PROGRESS REPORT

WASHINGTON UNIVERSITY PROGRAM

On

APPLICATION OF SATELLITE COMMUNICATION

To

EDUCATIONAL DEVELOPMENT

submitted to

OFFICE OF UNIVERSITY AFFAIRS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

January 20, 1970

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INTERNATIONAL DEVELOPMENT
TECHNOLOGY PROGRAM

WASHINGTON UNIVERSITY
SAINT LOUIS, MISSOURI 63130

TO BE OFFERED SPRING 1970

IDTS 591 Special Topics in International Development Technology

Satellite Communication for Educational Development (3 credit hours).

Prerequisites: Permission of Instructor

This course will examine the potential impact of satellite communication for bringing about improvements in education in the United States. Part of the course will be devoted to a careful appraisal of past and present proposals for satellite and airborne systems. Major effort will be directed towards developing a system which can effect improvements in education for disadvantaged groups where needs are the greatest.

The approach will be broad and interdisciplinary. Topics to be considered include:

1. Hardware requirements (e.g. TV-Receivers, New Developments in Educational Technology, Distribution Systems, Power Sources).

2. Allocation of the Frequency Spectrum for Space Broadcasting.

3. Economic comparisons of alternative distribution systems (satellite, cable, films, etc.)

4. Political, Social and Legal Factors, (Role of FCC, Comsat, etc.)

5. Education. How People Learn. Use and Effectiveness of Media for Teaching Literacy, Training Teachers, Math. and Science Education, etc.

6. What are the Educational Needs of the U.S. and Potential User Groups for a Satellite System? (Alaska? Appalachia? Migrant Workers? Inner City Groups? Prisons? Physically Handicapped?, etc.)

7. What organizational Structure for a satellite system? NET? CPB? Commercial? Government? University?

8. What should the program content be and who should control it?

9. Comparisons with planning and implementations for systems in other countries, e.g. India and Brazil.

Recommended for interested graduate students and seniors, with permission of instructor. Ideally, I'd like to have a minimum of 2 or 3 electrical engineers, 1 or 2 computer scientists, 1 chemical engineer or mechanical engineer, 1 applied physicist, 3 education majors, 1 or 2 law students, 1 or 2 political scientists, 2 economists, 1 or 2 sociologists or anthropologists, 1 psychologist, 1 or 2 social workers and one or more business or public administration types. (Plus any one else who is really interested!) Hours to be arranged. Guest speakers from both on and off campus.

For further information, contact Prof. R. P. Morgan, Room 413A Urbauer, Box 1140, Phone 4123.

PROGRESS REPORT

WASHINGTON UNIVERSITY PROGRAM

ON

APPLICATION OF SATELLITE COMMUNICATION

TO

EDUCATIONAL DEVELOPMENT

I. BACKGROUND AND OBJECTIVES.

On September 1, 1969, Washington University initated a program on Application of Satellite Communication to Educational Development, funded by NASA's Office of University Affairs. The broad objectives of the program are:

1. To analyze the role of satellite communication as a means of improving education in the United States and in less-developed areas of the world.
2. To generate basic knowledge which will be useful in making rational decisions about satellite application in the field of education in the years ahead.
3. To devise systems and strategies for improving education utilizing satellite communication and to carry out experiments which may be necessary to evaluate the effectiveness of such systems.
4. To provide "advanced interdisciplinary training of communications experts--economists, lawyers, engineers, management experts, social scientists and others...to deal with problems of communications policy which transcend the confines of any single discipline". (From Report of Président's Task Force on Communications Policy, Dec. 1968)[1].

This report summarizes progress made during Phase I of the research program and defines the effort to be undertaken during Phase II. The objectives sought in Phase I are described in a letter from R. P. Morgan to H. B. Quinn, a copy of which is appended to this report.

II. PHASE I ACCOMPLISHMENTS.

Among the most significant accomplishments to date are:

A. We have succeeded in establishing the necessary working relationships between diverse segments of the Washington University community which are essential for insuring the long-term success of this interdisciplinary endeavor. Key elements in achieving this condition have been; a) strong interest on the part of faculty members and students from a variety of disciplines in a program which relates technology to pressing social problems, b) good inter-school and inter-personal relations which exist in a university of the size and scope of Washington University, c) a small core of individuals who constantly keep the total program requirements in mind. This latter "glue" which holds the program together and prevents fragmentation is supplied by the International Development Technology Center, which emphasizes the application of science and technology for development. The Center, which cuts across departmental and school lines, will be designated as an Inter-School (All University) Institute effective July 1, 1970, reporting to the Vice Chancellor for Research. We are confident that the existence of the Center provides the necessary framework for insuring the success of this broad-gauged, interdisciplinary program.*

B. A comprehensive review of past and present activities related to both international and domestic satellite application to the field of education has been undertaken. Suitable reports are being prepared and an information retrieval system is under development for handling this information. There is a voluminous amount of information available if one views the satellite-education field from a broad vantage point as we are endeavoring to do. Information has been obtained by a combination of searches of library and information retrieval sources and by first-hand visits. This effort is being headed by Herbert Ohlman, an expert in information science and engineering, who was formerly deputy director of the Central Midwest Educational Research Laboratory (CEMREL) and who is now pursuing the D.Sc. Degree at Washington University in Applied Mathematics and Computer Science.

*A recent article about the Center appeared in the November, 1969 issue of "Engineering Education" (See Appendix H)

C. In accordance with Phase I objectives, one "sub-program" has been identified as the focus for detailed interdisciplinary analysis and experiments during Phase II. This domestic (U.S.) system we have called the "Equal Educational Opportunity Satellite System", capable of delivering a large number of programs to different user groups. The key idea is to transmit voice plus still pictures in order to accomodate a large number of programs within a limited bandwidth. The audio-visual programs can be received selectively by a wide variety of audiences,such as migrant workers, Indians, students at secondary schools, inmates at penal institutions, etc. The system will be designed to maximize individualized instruction and feedback. The system will also emphasize local control of programming materials.

Scientists and engineers such as Clarke,[16] Licklider,[5] and Bretz[4] have emphasized the potential and the need for further research in this field, which Bretz has classified as "still-picture television". Our initial studies will emphasize a "time-shared" rather than a "slow-scan" approach[4]. Overall studies will consider facsimile transmission via satellite for delivering permanent supplementary educational materials. The system is described in more detail in Appendix A and the specific research tasks to be undertaken are described in Section III.

It is anticipated that the "sub-program" described above will constitute approximately 90% of the total Phase II effort. It was our intention at this time to define another sub-program which was to constitute a cooperative effort between our International Development Technology Center and a university or research organization in a developing country. We are not now in a position to define specific research tasks which might constitute the basis for such a cooperative effort. However, a recent trip to India by R.P.Morgan, Program Coordinator, has opened up the possibility of future cooperative efforts involving individuals in one or more Indian institutions in both ground-based hardware and software aspects of satellite education systems.

The 1972 NASA-India Satellite ITV experiment[19,20] and subsequent plans for Indian and Brazilian national satellitesystems would appear to have important implications for the United States as well as for other countries. Interaction through cooperative research would appear to be very much in our national interest, and we stand to learn much from such cooperation. Furthermore, such efforts are in accord with two of the principal program goals enumerated by the recent Task Force evaluation of future NASA programs headed by Vice President Agnew, namely,a) international cooperation, and

b) the application of space technology for the benefit of all mankind[2].

Therefore, should the opportunity arise, we plan to devote a small amount of program funds to international cooperative program efforts. We shall keep NASA's Office of International Affairs fully informed of any activity of this nature which may develop.

D. A "Phase II" program effort has been defined which involves a well-integrated teaching and research effort. Students and faculty members will participate by attacking specific research tasks and by sharing their experiences through involvement in carefully designed courses. Many of the research tasks are related to overall systems studies but also represent bonafide explorations within the context of the departments in which students are enrolled. Thus, it should be possible to avoid, on one hand, a situation in which a multidisciplinary research project is nothing more than a group of individuals "doing their own thing", and on the other hand, a situation in which studies with very little depth are produced. We view this program as an experiment in providing a new kind of experience for students and faculty members which will bring university resources more effectively to bear on problems of our society. The nature of this experience and the mechanisms employed to make it work are described further in the Appendix.

Items A through D above are keyed to the objectives itemized in the letter from R. P. Morgan to H. B. Quinn on August 13, 1969. (See Appendix I). Among the specific activities undertaken during Phase I to achieve these objectives were the following:*

1. Preliminary background studies and explorations were made by research assistants and associates in the fields of law, economics, electrical engineering, education and information science.
2. Approximately 25 undergraduate students and 15 graduate students were exposed to the subject of satellite applications for education in two interdisciplinary courses offered by the International Development Technology Center. One of these courses was oriented strongly to U.S. needs. Many students chose to do term papers related to this subject.
3. Meetings were held, on the average, once a week to explore in depth the significance and promise of satellite applications in the field of education, particularly for the United States. Among the key participants in these meetings were:

* The following description includes a small amount of related activity carried out in the summer of 1969 under a NASA grant.

Prof. R. P. Morgan (International Development Technology Program) Program Coordinator

Prof. R. M. Walker (Physics)

Prof. F. J. Rosenbaum (Electrical Engineering)

Prof. D. L. Snyder (Electrical Engineering)

Prof. B. Anderson (Education)

Prof. E. Greenberg (Economics)

Prof. N. J. Demerath (Sociology)

Prof. N. Bernstein (Law)

Mr. H. Ohlman (Research Associate and PhD Candidate, Applied Math and Computer Science)

Mr. M. Hurtado (PhD Student, Electrical Engineering)

Mr. A. Sene (M.S. Student, Electrical Engineering)

Mr. S. Haberman (PhD Student, Economics)

Mr. G. Walker (PhD STudent, Education)

Mr. J. Scheiner (3rd Year Law Student)

Mr. J. DuMolin (Research Assistant, Educational and Socio-Political Aspects of Satellite Utilization)

It is anticipated that most of the above individuals will play important roles in Phase II of the program. Six faculty members listed above, and Dr. R. W. Johnston, Vice Chancellor for Research, will constitute a "task force" responsible for providing the necessary program direction. The students have all been involved to varying degrees. At least four PhD theses, which will be defined in the Section on Phase II activity, have been identified.

These meetings have been of major importance in creating the cohesiveness so essential for the success of an interdisciplinary research project. They have led to the identification of an equal educational opportunity satellite system, using voice and still pictures, as the major sub-program of Phase II.

4. A number of key visits were undertaken during Phase I which relate to this program. Visitors to Washington University included Dr. Walter Radius (NASA) who spoke to the group on public policy factors of importance in the satellite application field, and Dr. Bruce Lusignan (Stanford) who spoke on systems engineering and ground-hardware considerations in satellite applications. Informal discussions were held with Prof. Merton Barry, Director of Engineering Foreign Programs at the University of Wisconsin, and a member of

that University's Educational Satellite Committee.

In addition to two visits by Washington University personnel to NASA Headquarters, visits and meetings attended included the following:

a). H. Ohlman, (Research Applied Scientist) chaired a session on information coding and compression techniques at the Annual Meeting of the American Society for Information Science. He also visited with Prof. Lyle Nelson, head of the Department of Communications at Stanford University.

b) J. DuMolin (Research Assistant) attended a NASA review meeting on Information Satellite Transfer Requirements for the 70's at the Ames Laboratory.

c) H. Ohlman (Research Applied Scientist) attended a Conference on Image Storage and Transmission Systems for Libraries at the National Bureau of Standards.

d) Discussions were held with Mr. Robert Glazier, Director of the St. Louis Educational Television Commission and manager of KETC-TV, Channel 9, St. Louis.

5. The Program Coordinator (R. P. Morgan) spent two weeks in India and had an opportunity to have discussions with top officials of the NASA-India, Satellite - ITV experiment. He also was appointed co-chairman of the session on Systems for Emerging Nations at the 3rd AIAA Satellite Communication Systems Conference to be held in Los Angeles in April, 1970.

In summary, we feel that we have fulfilled to a large degree the objectives which were set forth for Phase I of this program. A detailed description of Phase II activity will now be presented.

III. PHASE II ACTIVITY.

In this section, we shall describe a variety of interrelated activities which constitute the Phase II program effort. In a recent study on the emerging role of the university in general, and MIT in particular, Jantsch (3) has pointed out that an alarming split in purpose and operation exists among the three functions of education, research and service. This split hampers the university in its efforts to become more effective in contributing to the solution of pressing social problems. The program to be described represents a partial reintegration of these functions to provide a total experience which will yield useful results.

A. Course Work. During the spring semester of 1970, course IDTS 591, Special Topics in International Development Technology, will be devoted solely to the topic of Application of Satellite Communication to U. S. Educational Development. The course will be divided into three parts:

a) Background: Technical and non-technical factors of importance in satellite-education, presented in a manner understandable to students in engineering, economics, education, sociology, law, political science.[1,3,10,11,14-18]

b) Case-study evaluation of past and present proposals for satellite and other relevant technological applications to the field of education, e.g., MPATI,[6] EDUSAT,[14] Rand-707 study,[7] etc.

c) Concentrated analysis of an equal educational opportunity satellite system.

This course, which is offered for credit to graduate students and seniors, will be a major convergence point for the diverse interests of the various program researchers and personnel. We intend to use this course as the basis for the development of two books, a) an edited compilation of relevant, current articles in the satellite-education field, b) an original contribution based upon our own thinking and effort. A description of the course is shown on the following page.

It is anticipated that future courses will also relate to the satellite-education program. Under discussion now are plans for devoting a sizeable portion of a new design program in the School of Engineering and Applied Science to the design of an integrated low-cost receiver/front end/power source for direct reception of satellite signals in unelectrified areas. Other ideas for new courses and even new interdisciplinary programs and degree arrangements may be generated from this effort to tie the research tasks closely to the academic program and the educational process.

B. Research Tasks. The following research tasks have been identified, most of which will be undertaken during Phase II. It is anticipated that others will surface during the continuous process of interactive examination to which the total program will be subjected. Where more than one degree designation is indicated below, it is anticipated that more than one dissertation will result.

1. Analysis of an Equal Educational Opportunity Satellite System. (M.S., PhD; Applied Mathematics and Computer Science, Education; Professors Morgan, Walker, et.al).

This study will provide an overall evaluation of a satellite system for distributing voice, still pictures and supplementary educational materials to a wide variety of users. In a recent Rand Corporation Report,[4] Bretz has pointed out that still-picture television is the most promising unexplored telecommunication medium. Emphasis will be upon a logical synthesis of user needs, technical capability, economic factors, organizational requirements, socio-political and legal factors, and educational technology and effectiveness considerations. In other words, it is anticipated that at least one or two theses will represent in microcosm the total program effort.

The system concept includes distribution of supplementary educational materials such as tables, charts and study guides for individual student use by facsimile transmission via satellie. Key features to be built into the system are broadcast bandwidth conservation, individualized access, feedback and local programming control. Overall systems simulation will be undertaken. The rationale for focusing on this system and the approach to be followed are presented in more detail in the Appendix.

2. Economic Analysis of Satellite Communication Systems for Education* (M.S. PhD; Economics; Professors Greenberg, Morgan)

The proposed research will involve the economic analysis of satellite communications systems which have potential for improving education in the United States. Two kinds of studies are envisioned:

a. Comparative studies of alternative systems for transmission and distribution of educational materials. Emphasis will be placed upon the distribution of voice signals and still pictures. Such material may represent an attractive alternative to either television, with its large bandwidth requirement, or radio with no visual image at all. [3,5] Previous economic comparisons of the type envisoned have been carried out for regional transmission of television in the MPATI program [6] and for distribution of microfilm [7]. In this study, alternatives (satellite, airplane, cable, mail,) or some combination of these will be analyzed for transmission of voice plus still picture. A similar comparison may be undertaken for distribution of supplementary educational materials for individual

*This project will be supported in part from NASA grant NGR 26-008-003 during the 1969-70 academic year, R. P. Morgan, Principal Investigator.

student use by facsimile transmission via satellite versus other transmission modes.

b. Comparative studies of the costs and/or effectiveness of educational satellite-distributed media. A recent study by Jamison (8) has argued that radio is a more cost-effective medium than television for educational use in connection with a proposed satellite system for Brazil. We wish to examine this analysis but within the context of potential U. S. educational satellite systems. Different alternative media such as radio, TV, and an intermediate audio-visual approach will be considered.

3. Analysis of a Multi-Channel, Low Video Frame-Rate, Continuous Audio, Television Transmission System(M.S., PhD, Electrical Engineering, Profs. Snyder, Rosenbaum)

A multi-channel scheme is envisioned for relaying the educational material discussed previously. In each subchannel there must be a capability for a continuous audio signal (voice, music, etc.) and a companion low frame-rate video signal; that is, a video signal with frames (pictures) that change infrequently compared to conventional television (for instance, once each ten seconds). Higher frame rates than can be achieved with a single subchannel may be required from time to time for certain educational material. Consequently, provision must be made for the simultaneous use of more than one subchannel to achieve a variable frame rate capability. It is also envisioned that individual frames have about the same quality reproduction as conventional television.

The multi-channel signal received from the satellite must first be preprocessed so that a desired subchannel is placed into a form that is compatible for display with a conventional television receiver. This preprocessing may be done remotely from the display receivers, many of which can then be connected, for example, by cable (commercial CATV) to the centrally located preprocessor. At the opposite extreme, the preprocessor may be colocated with a few (or each) display receiver, in which case the complexity and cost of the preprocessor are extremely important.

There are several important technical considerations that must be identified and carefully examined before such a television transmission system can be designed. System constraints must be defined; among these are carrier frequency, available bandwidth, available power, link (i.e.

channel) characteristics, number of video-audio subchannels desired, location of preprocessing, etc.

Preliminary consideration has been given to a frequency-multiplexed audio, time-multiplexed video modulation scheme that is compatible with conventional television bandwidths and modulation. With this approach, a portion of the available bandwidth is allotted to multiple audio subchannels which are frequency multiplexed (i.e., placed in adjacent frequency bands) for continuous transmission of audio information. The use of several audio subchannels thus requires a larger fraction of the available bandwidth than the single audio signal in conventional television. This expanded audio bandwidth may be accomodated without compromising the quality of individual video frames by decreasing the video frame rate an appropriate amount. Of course, intermodulation effects are important here and need to be considered carefully.

Each subchannel of video information consists of still pictures that are updated infrequently. These still pictures are time multiplexed into the transmitted video signal as an ordered sequence of individual frames; (See Figure 1) thus, if there are N subchannels of audio-visual information, frames 1, N+1, 2N+1, 3N+1,... correspond to subchannel one, frames 2, N+2, 2N+2, 3N+2,...correspond to subchannel two, etc. The updating rate for each video subchannel is 1/N times the frame rate of the transmitted signal. A frame synchronizing signal will be required to identify the beginning of the frame sequence. The preprocessor then counts frames from the frame synchronizing signal (e.g., by counting vertical synchronizing pulses) to the frame corresponding to the desired subchannel. This frame must then be stored in a video frame buffer (possibly a short length of video tape or a drum). Between updatings of the buffer, the stored video frame, which corresponds to a single still picture is read periodically and combined with its companion audio signal to generate an audio-visual signal compatible with the conventional television receiver used for display.

Thus the overall transmission system envisioned is analogous to a broadcast system in which audio information is obtained in the usual way by frequency selection, but video information is obtained by a time synchronized selection of frames from a sequence of frames. The selected audio and video frames must then be preprocessed so they can be displayed with a conventional television receiver. Such a scheme has the advantage

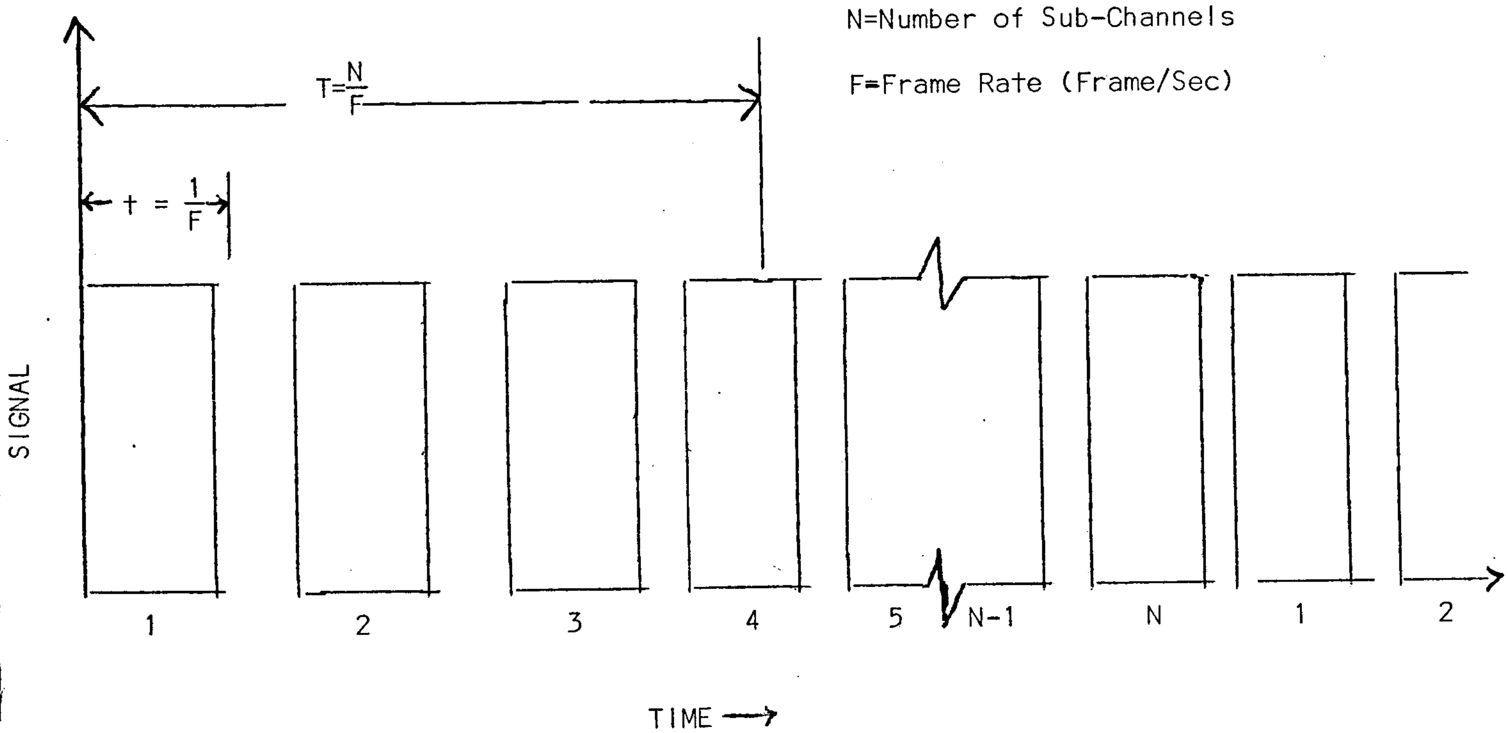


FIG. 1. TIMING SEQUENCE OF SUB-CHANNEL FRAMES

that a subchannel frame rate can in effect be increased by simply selecting frames more frequently from the sequence of frames transmitted. (This, of course, reduces proportionately the number of available video subchannels).

The transmission scheme outlined is tentative, but appears to have enough merit to warrant deeper study in Phase II of the program. The research in Phase II would consist of: (1) identifying the system constraints quantitatively; (2) defining and evaluating tradeoffs for various modulation or coding schemes that meet the system constraints (a candidate here is the system described); (3) defining and evaluating tradeoffs for various demodulation schemes; (4) Initiating receiver design (for example, consideration needs to be given to designing the video buffer and composite television signal generator in the scheme outlined).

4. Microwave Device Research Relevant to Satellite Communication Systems (PhD, M.S., Electrical Engineering, Prof. Rosenbaum)

There is currently underway at Washington University a vigorous program devoted to the operation and application of "Gunn Effect" devices, a type of low-cost microwave solid-state oscillator. There is also some effort being spent on microwave integrated circuit problems. Basic research on such devices as well as more applied research directed towards the development of circuit elements and receivers of various types is likely to yield basic knowledge which will be useful in making rational decisions about hardware for education satellite systems in the future. For this reason, we plan to support one PhD candidate in a basic microwave research study. He will be a well qualified and active participant in the overall satellite education program effort who will be in a position, along with Professor Rosenbaum, to identify promising applications. In this manner, we hope to reduce the time lag between basic research discoveries and their application.

There are a number of potential devices which might incorporate the kinds of microwave components or circuits under study at Washington University. These could include low-cost, rugged TV receivers, adapters for TV's which permit display of still pictures, equipment at other system points in which microwaves are received. However, before devices based on the Gunn effect can be used in low cost, high performance applications, several aspects of their operation and control must be understood. In this research, we will reproduce required circuit functions in microstrip, a planar transmission system well suited for production quantities using photo-lithograph techniques. The hardware problems to be studied in this development include the stabilization of a microwave solid-state oscillator in this geometry; microwave automatic frequency control; noise behavior of these oscillators; circuit functions in microstrip; integration of mixers; low cost power supplies; environmental packaging, etc. While we cannot hope to solve the multitude of technical problems described here we feel that we can obtain an insight into the overall systems requirements and develop engineering trade offs.

In this effort we have back-up support from the Monsanto Company, suppliers of Gunn effect devices and the facilities of the Washington University Computer Components Laboratory which has full scale capability in low frequency integrated circuits. A more detailed description of the Washington University Gunn-Effect research program and capability is included in Appendix D.

5. <u>The Educational Impact of Educational Satellite Systems</u> (PhD, M.S.; Education; Profs. Anderson, Morgan)

There is currently great dissatisfaction with and unrest in the U.S. school system. Large urban high schools have drop out rates of over 50%. Illiteracy still remains a problem. Other groups singled out for study in the Coleman report, [9] such as American Indians and Spanish-speaking Americans are not being afforded equal educational opportunity. The problem of providing such opportunity should be a major focus for national effort in years ahead. [10,13]

There is a pressing need for the technologist to understand the realities of our educational system and needs, and for the educator and policy maker to understand the opportunities and limitations which are inherent in any technological innovation. [11] As a consequence, we have begun a study of the impact of the new media and, in particular, an equal educational opportunity satellite system on U. S. education. Such a study should yield new insights into the problems and possibilities.

Being considered are questions of teacher acceptance of technological innovation, effectiveness of media, particularly for the disadvantaged, and organizational problems associated with a satellite system. A preliminary statement of some initial considerations is included in Appendix C.

It is anticipated that this study will focus down on other specific problem areas such as the following:

a. Details and requirements for a particular geographic region, e.g. Alaska and the Western U. S.

b. Requirements for specific user groups and curricula, e.g., high school mathematics, pre-school children, etc.

c. Media Utilization (See 6. Below)

6. Educational Utilization of Voice Plus Still Picture Transmission (PhD, M.S.; Education; Profs. Anderson, Morgan)

Although some studies have been carried out to evaluate the effectiveness of voice plus still picture presentations for education,[12] much work remains to be carried out if such media are to be used effectively. The advantages of utilizing this combination in terms of bandwidth savings has already been discussed.

We will develop some materials and use them at one or more age levels in the St. Louis area. We currently are considering two specific learning experiences; high school-level mathematics and introductory computer logic, and 2) spelling. We plan to undertake these projects in the St. Louis Community with the cooperation of such individuals and groups as Robert Glazier, Program Manager, Station KETC-TV (educational television), St. Louis, and the Multi-media Student Laboratory at the University City (Mo.) High School. We plan to involve inner city high school students in making the program materials.

7. Legal Problems Associated With the use of Communication Satellites For Educational Development (Law, Professor Bernstein)

Any proposals to use communications satellites for the transmission and dissemination of educational materials, either within the United States or in other countries, necessarily raise a host of legal problems. These problems run the gamut from questions relating to international public laws and treaties, through national methods of allocating spectrum and barring extra-territorial transmissions, to problems of rights to own, control and utilize specific materials and programs. Although a number of these problems have been investigated to varying degrees, the results are uneven and uncoordinated.

Three specific legal research studies are presently contemplated:

(a) A general background study will identify the major legal issues that will be created by any satellite educational system and anaylze in detail the state of existing law with respect to each issue. This study will produce a much needed compilation of existing legal research as well as an identification of the significant areas which have not been satisfactorily explored to date. The study should furnish insight for the non-legal participants in the program into the legal parameters which must be considered in overall systems studies in addition to providing a valuable starting point for future legal research. This study has already begun (See Appendix E.

(b) Ihe equal educational opportunity satellite system described in section II C supra, will be examined from a legal standpoint. The study will indicate the extent to which the proposed system, as it develops, is consistent with existing law and the specific modifications of the present system that must be made before such a proposal can be put into effect. The legal questions raised under item c below are anticipated to be of primary importance.

(c) An in-depth study will be undertaken of questions of ownership and control of programming material transmitted over a domestic educational satellite system. This study will attempt to answer questions such as the following:

(i) Would such a system be able to use existing materials presently in suitable transmission form without the consent of the authors, producers or participants originally responsible for such materials?

(ii) Could audio-visual educational materials be developed from material presently in forms not suitable for satellite transmission (such as books) without the consent of the original creators of such materials?

(iii) What rights would the authors, producers and participants in materials developed for the system have in the resulting product? Would its transmission and dissemination in the manner proposed limit or destroy those rights?

(iv) If materials are transmitted to a memory bank for storage and selection by individual users, could such users make revisions or deletions in the materials without the consent of the original creators?

(V) Could such materials be made available for use in public school classrooms throughout the country without prior screening and approval by state or local boards of education?

(VI) Do any doctrines of the Federal Communications Commission, such as its "fairness" doctrine, place affirmative obligations on such a system to disseminate or refrain from disseminating any particular materials?

Special emphasis in this study will be placed on the United States Copyright Act of 1909 and the proposed revisions thereto presently pending in Congress.

8. Other Research Topics

There are a number of other directions which the research could take during Phase II, depending upon the interest shown by faculty members and students at Washington University. Significant policy questions such as international organization for satellite utilization and cluttering of orbital space need not be separate research tasks but can be dealt with in courses or seminars. Expressions of interest may develop further from the Indian Space Research Organization or the Indian Institute of Technology, Kanpur between now and April, 1970 when the Program Coordinator with co-chair the 3rd AIAA Satellite Communication Systems Conference Session on Systems for Emerging Nations. Cooperative efforts in hardware-oriented research are possible.

For example, one of the least researched but potentially important technical fields of interest in the satellite field is the power source for the receiver package in remote areas with no electricity. Domestic applications include Alaska and Micronesia. In India, by 1979, it is estimated that only 15 to 20% of 560,000 villages will be electrified. Studies of the use of media in family planning may also emerge. A small amount of program funds might be utilized in such an effort.

It should be pointed out that all of the research tasks defined above in Items A through G are directly relevant to application within the United States. It is further anticipated that a major portion of the funds committed to Washington University at this time ($200,000) will be directed toward U. S. application. However, should the need and opportunity arise, we would like to devote a small amount of these funds to cooperative research efforts between our International Development Technology Center and individuals in developing countries. We stand to benefit greatly as a nation by learning from the experiences of others who are moving ahead with satellite education experiments. For this reason, as well as the fact that such cooperation is consistent with NASA program objectives to participate in cooperative international efforts and extend the benefits of space science and technology to all mankind, we would not wish to rule out the possibility of utilizing some resources in ways which might seem more relevant to other countries than the U. S.. However, it should also be kept in mind that in many instances, it is difficult to separate the two. For example, a satellite system which distributes a large number of audio and visual (still picture) signals might be of great interest and utility in other parts of the world as well as the U.S.

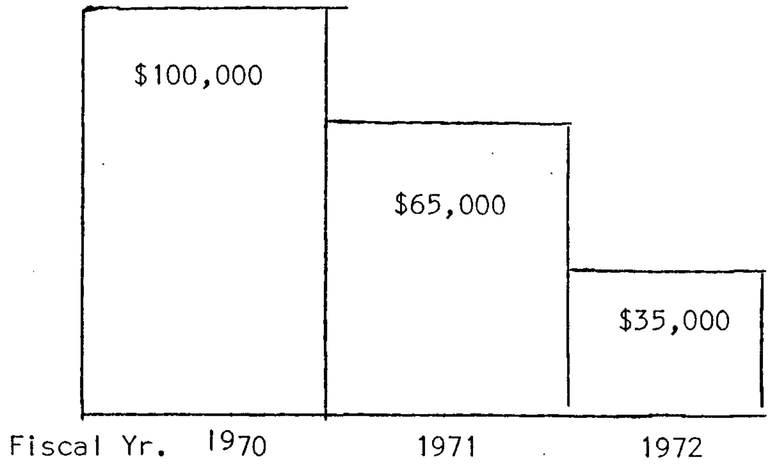
C. Other Program Elements.

During the spring of 1970, plans for additional program elements will be developed. One possible future program direction, involving cooperation with Indian institutions, should move towards a decision point. In addition, we will expand our contacts with potential program users and consultants (students, educators, broadcasters, government officials, etc) in the St. Louis area and elsewhere.

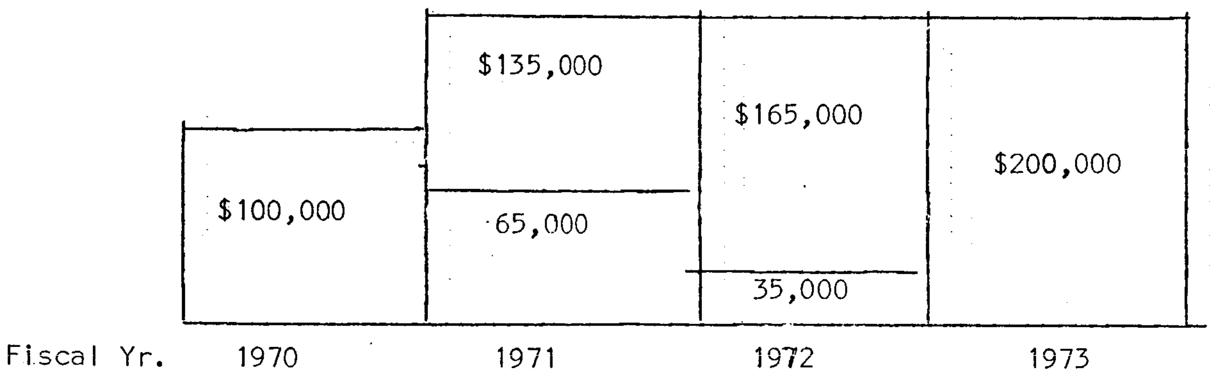
We will also begin to plan one or more workshops which will bring together people from the university and the community to explore important issues such as the impact of satellite communication on educational needs. The first such workshop might be held as early as the summer of 1970.

IV. FINANCIAL REQUIREMENTS.

The current NASA grant for this program is for a total of $200,000 over three years, step-funded downward as follows:



Prior to April 1, 1970, we plan to submit a request for an increase in budget as shown below:



The emphasis in the NASA-funded Office of University Affairs grant will remain technologically centered and primarily domestic oriented. The additional funds will enable us to continue our efforts and to undertake some meaningful experiments involving new hardware and educational technology.

We also plan to approach A.I.D. and the Office of Education for additional funding in connection with international and software aspects. However, this does not alter the need for the kind of significant NASA funding requested above.

V. CONCLUSION.

We hope that this report demonstrates that we have made good progress towards meeting our program objectives. We believe we are undertaking a unique and significant program which is truly multidisciplinary and which has the potential for coupling technology to social problems in an effective way. We wish to reiterate that the program is most relevant to the needs of NASA and the needs of the United States in the following ways:

a. It emphasizes the application of space science and technology to help solve the educational crisis facing our nation and the world.

b. It will train future professionals in a variety of disciplines who can fill a vital need in both the public and private sector for individuals who are knowledgeable about broad areas of application of the national aeronautics and space program.

With continued support of the kind indicated above, we believe that we can successfully create a new form of university experience which will be a leading example of how universities can meaningfully respond to societal needs; a program which the supporting agency, NASA, can point to with a sense of accomplishment.

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APPENDIX A

"EQUOPS" An Equal Educational Opportunity Satellite System

by R. P. Morgan

"The point to remember is that the birth of a technological innovation, such as communication satellites, is a moment when institutional arrangements and practices are bound to be considerably upset. It is an opportunity to modify institutions and policies in ways that may not necessarily or directly by connected with the technical innovation itself. Thus, within the United States, the desire for a public television service to raise standards is being linked to the emergence of satellite communications. Similarly, in the world there is an opportunity here to create better institutional arrangements and practices", from report on "Communication Satellites" by Stockholm International Peace Research Institute, Gunnar Myrdal, Chairman.

The purpose of this section is to define a system which will constitute the focal point for much of our effort during Phase II of our program. It is important that there be a unifying theme or system that a lot of people from different disciplines can relate to. Such a theme or system can form the basis for multidisciplinary courses and for the interchange of ideas between technologists and non-technologists. Individual research tasks can be continually defined and redefined as a result of such interaction, and more basic research efforts, while relevant in their own right, can be continually scrutinized for potential application.

However, a word of caution is required at the outset. First of all, we are <u>not</u> advocating one system at the expense of all others, nor do we require at this stage of the game that all of the specific research tasks to be undertaken under the overall program necessarily appear to be those most immediately relevant to the system to be defined. We reserve the right to have some flexibility in those things we undertake and to change directions if the need warrants. If a multidisciplinary research effort carried out at a university is to succeed, this kind of flexibility is essential.

The system we have begun to examine we have termed in this era of pneumonic proliferation, EQUOPS, an Equal Educational Opportunity Satellite

System. In general terms, we are directing our efforts towards a system which can aid in providing improved educational opportunities for disadvantaged groups and people in society. This effort to couple technology to pressing social problems in an intelligent, sensitive and effective manner is the dominant theme of our overall program.

Our primary concern will be with a system that is applicable and relevant to educational needs in the United States. In general, much less careful attention has been given to educational satellite applications in the United States than in developing countries. However, it is very likely that the ideas we are developing and the research which we are undertaking will be equally applicable to other countries. Furthermore, we stand to learn much and to benefit greatly from interaction with satellite application programs and studies in the international area.

Some of our preliminary discussions have indicated that satellite transmission of educational materials might have greatest impact in widespread, remote areas or in areas where the infrastructure for alternative means of transmission has not been constructed. This kind of analysis has been responsible for the strong interest in satellite systems in countries like India and Brazil. A number of ideas have been proposed for domestic area-specific or group-specific studies such as Alaska, Alaska plus the sparsely populated Western States, Appalachia, and Migrant Worker areas. These kinds of studies are of interest to us and can be pursued within the framework of the proposed program.

However, the system which we initially are examining in detail is one which is not area specific or group specific. It is a system which, because of its large, multi-channel capability, could be used by a variety of groups in a variety of regions. The multi-channel capability is achieved by utilizing a combination of audio-channels plus still pictures. Such a system permits a large number of programs to be broadcast in the bandwidth of one television channel, thereby saving on the in-air spectrum requirements, a key limitation for future broadcasting.

The basic idea of utilizing voice plus still pictures is not new. In some of his earlier writing, Arthur Clarke, the godfather of communications satellites proposed an "electronic blackboard", which he describes as "presenting the possibility of an interesting compromise between radio and full-scale television." According to Clarke:[1A]

"It should be possible to develop a cheap and simple slow-scan facsimile-plus-sound receiver which could operate on the normal radio-bandwidth, without requiring the approximately thousandfold greater spectrum space needed by television. Such a device could reproduce line drawings and cartoons (half tones would be unnecessary) at a perfectly adequate speed for educational purposes, where the same picture has to stay in view for a minute or more."

In an important supplement to the Carnegie Commission report on Public Television, J. C. R. Licklider discusses the problems and potentialities of using television in new and innovative ways.(2A) For example;

"Instead of broadcasting a "moving picture"-a succession of still pictures, each minutely different from its predecessor - the transmitter sends out a sequence of still pictures in which one is quite independent of the next. The still pictures, coming at a rate of thirty per second, constitute a vast informational resource from which each receiver can select. The receivers are designed to pick out certain images and to hold each one for view until its selected successor arrives. Thus the viewer sees a succession of still pictures, each selected from a large set of alternatives."

A recent review of the properties and uses of communication media by Bretz (3A) states that;

"Still-picture television is the most promising unexplored telecommunication medium. It appears to approach both television's universality of use and radio's inexpensiveness. Still pictures and sound may be broadcast in two ways, which are sufficiently different to justify classing the two as distinct media: slow-scan and time-shared television. Because neither of these is in acutual use today, except experimentally, they can be discussed only in terms of their inherent characteristics. How they could be applied is only speculation, but the indications are strong that they can be used for many instructional purposes. In a world where the usable electromagnetic spectrum is less and less able to accomodate all of the broadcasting demands on it, a system that can fit up to 300 still-TV channels into the space of one standard television channel may be very practical indeed, even if the lack of motion somewhat lowers its effectiveness. Some of the digital methods of encoding and transmitting still pictures developed for the space program may soon be applied, which could make this medium even more efficient in its use of the broadcast spectrum".

Figure 2 is a schematic diagram which shows some of the components of one configuration for the EQUOPS system. In addition to the delivery of audio plus video-still signals, a multi-media system might include transmission of facsimile by satellite. Facsimile represents a potentially attractive alternative to physically transporting "hard" copies of reference and supplementary study materials. Fig. 3 shows Receiving Center details .

A number of questions have been raised about the effectiveness of voice plus still pictures versus full-motion television. In particular, although not having full motion may be a psychological disadvantage, it need not necessarilly hinder certain kinds of learning. In fact, some have argued that certain kinds of motion can actually hinder learning and be distracting. One extremely effective use of audio plus still pictures which comes to mind was a history of the U.S. as seen through pictures shown on the Smothers Brothers TV show about one year ago. Further experimentation and evaluation is required.

There are a number of important system considerations which must be tackled at the outset. One relates to the attitudes of teachers towards use of media and their ability to control programs locally. Ideally, we would like to build into such a system the ability of the teacher to preview materials as to suitability for the classroom prior to actual utilization and to alter such materials as desired.

Another important consideration is to try to design a system which is realistic with respect to present and projected technology. Predictions for the potential growth of cable TV and improvements in cable technology might bring about a situation in which satellites are used to interconnect cities which are wired or which have rebroadcast or microwave link capability. The essential in-air transmission spectrum savings for a voice-still picture combination would still be an attractive feature of such a system. Cables with 20 or 40 channel capability also present the possiblity of thousands of channels for voice or still pictures with feedback.

The use of voice plus still pictures provides a potentially attractive alternative or supplement to full-motion television or radio. In Appendices B and C, some preliminary studies of facets of the EQUOPS system are described.

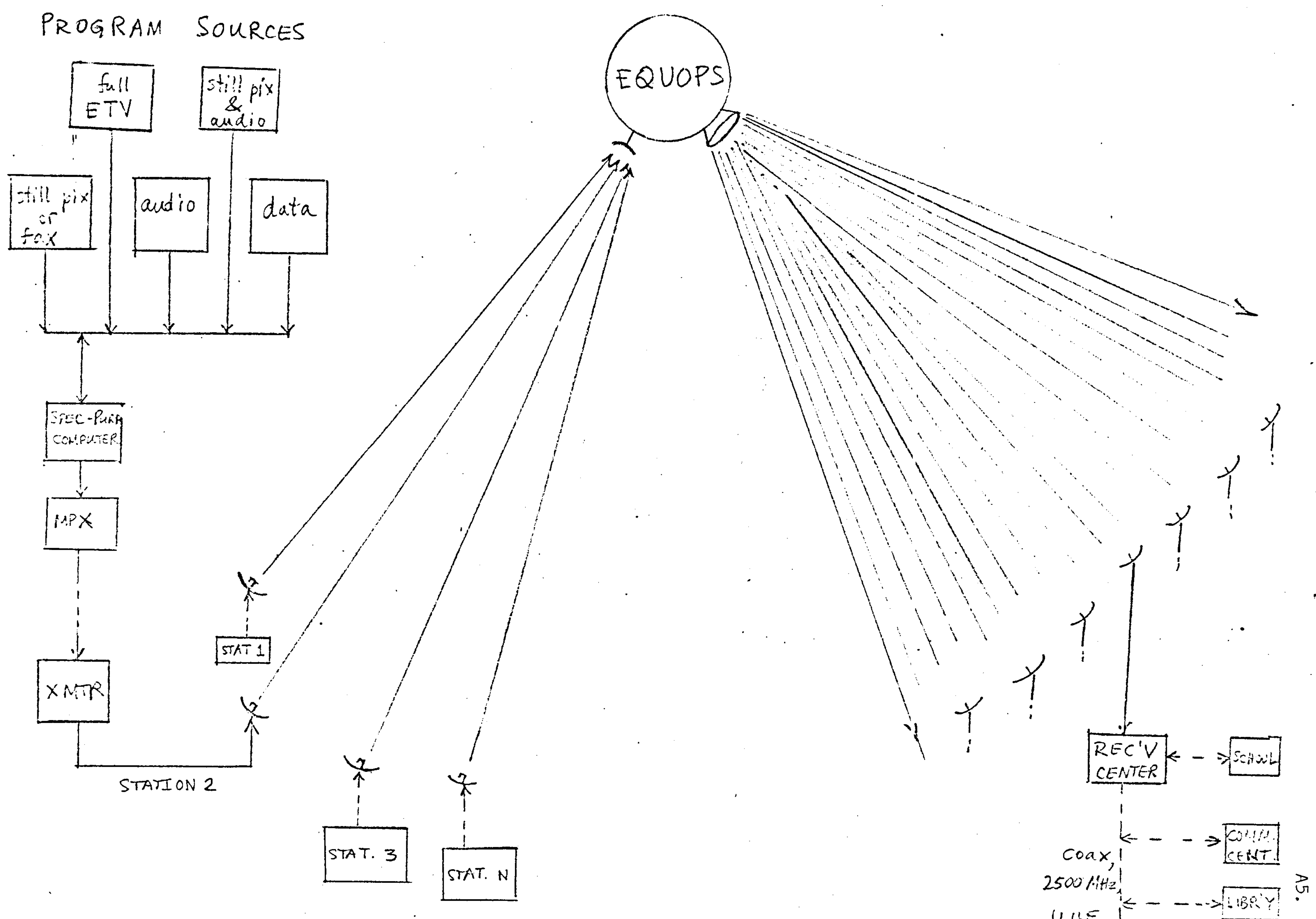

FIG. 2 EQUOPS SYSTEM

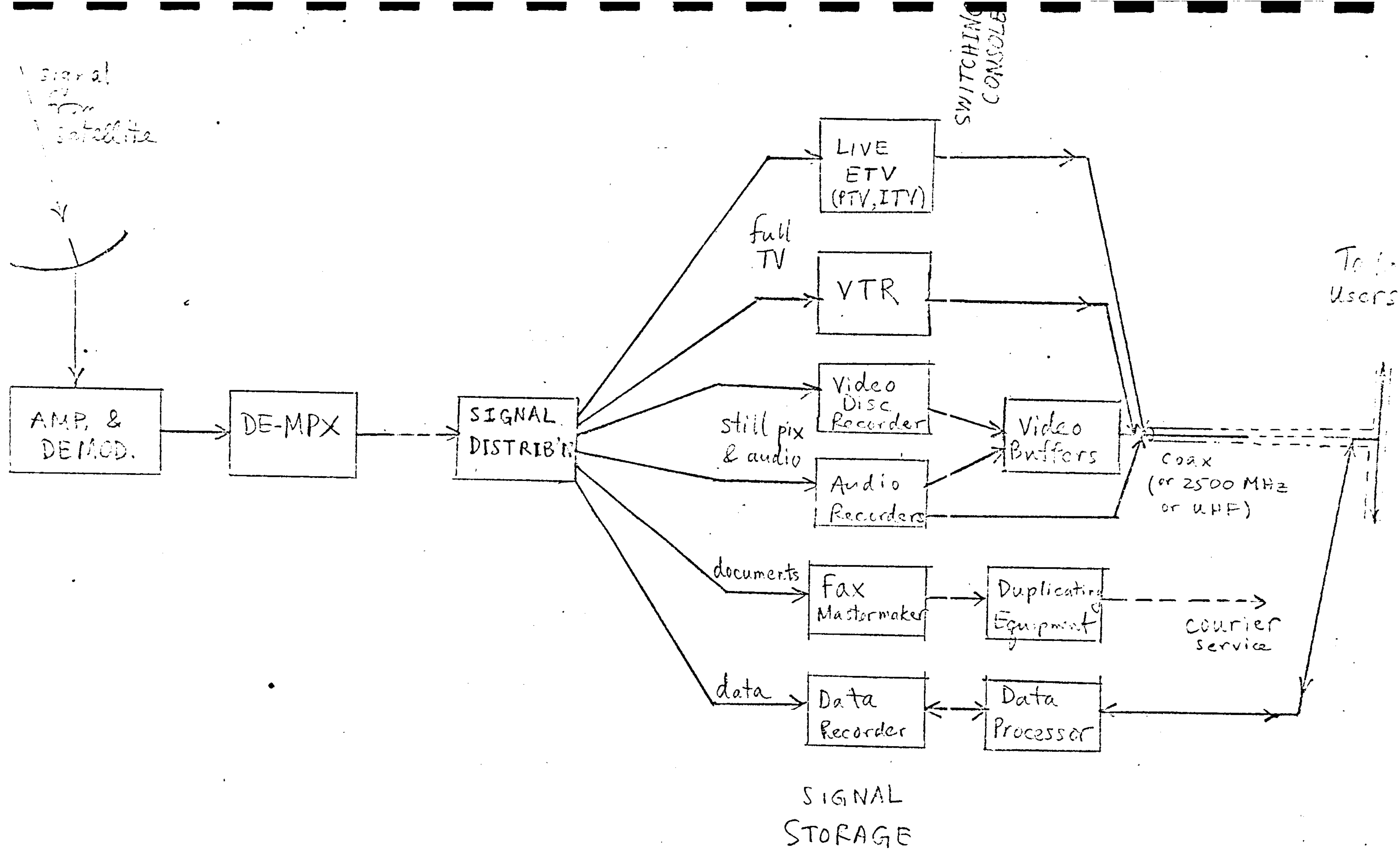

FIG. 3. FULL-COMPLEMENT EQUOPS RECEIVING CENTER

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APPENDIX B

Preliminary Ideas and Specifications for EQUOPS:
A Communications Satellite for the Dissemination of Audio-Visual Programs

By

Herbert Ohlman

This section contains some preliminary thoughts about the EQUOPS system. They represent a starting point for discussion and analysis and have not yet been carefully evaluated.

Almost all of the arguments so far put forth for educational communications are centered on the medium of educational television (ETV), while little attention has been given to other possible uses of educational communications channels. One of the few recent attempts to make a case for other media is a paper by Jamison, Jamison and Hewlett.[2B] They overstate the case for radio as "better than ETV", but nevertheless, it is worth considering what can be done by audio means alone. There is an enormous repository of material in this form. For example, the National Center for Audio Tapes has 12,000 audio productions available for instructional use. There is also a large and well-documented body of knowledge on audio-only presentation methods, both in this country and abroad.

A reading comprehension experiment by Travers and Jester showed no significant differences among audio, video, and audio-video versions at up to 200 words a minute, but as the speed of presentation was increased, auditory comprehension fell off much more rapidly than video--and the AV presentation showed an increased advantage over either single-channel presention[2B]. Also, Travers notes that in an AV presentation, each subject chooses the modality most effective for him. Thus a group of subjects can receive information better than when the information is presented through a single sense, which would tend to penalize some subjects. The importance of this latter finding for disadvantaged students, particularly those of poor reading skill, cannot be overemphasized.

What one should start with is the widely different capabilities of human learners, in relation to the instructional objectives of each subject. Certainly, large parts of such subjects as music and spoken-language learning are best appreciated through the aural sense, but just as obviously, a subject such as painting demands high-quality visuals. However, when we wish to discuss a painting with a student, it would hardly be a good solution to present the discussion in text when his eyes should be on the picture! Similarly when it comes to language, if our objective is to teach the written language as well as the spoken language (and in particular to develop both of these capabilities), there is great benefit in being able to see the textual material while hearing how it is spoken. Thus, one could divide a reasonably large part of the world of learning (that portion which doesn't require a large amount of motor inputs on the part of the learner) into three broad categories: audio only, visual only, and audio-visual.

A much more detailed breakdown can be usefully employed, as shown by Jack V. Edling [1B] in his paper "Media Technology and Learning Processes." Edling breaks media down by their degree of closeness to direct experience with people or with things (or in programmed-learning terms, by an increasing number of cues). Given such a model, one needs to so specify his educational objectives that he can decide from moment to moment in a learning experience whether to have a greater or lesser number of such cues.

From the economic point of view, we must consider what adding an additional increment of reality--that is, increasing the number of cues--buys us educationally. Although this question is probably unanswerable in general, rough limits can be set to the problem. If we neglect either of the two primary sensory modes, it would seem that we are not maximizing the use of the learner's time. This is a very tenuous assumption however, because when we are using a single mode of presentation, it is seldom saturated. Good learners can acquire information at much higher rates. For example, in silent reading, 500 to 700 words per minute is not uncommon for one trained in speed reading techniques. Similarly, the ear is capable of accepting information at a much higher rate than can be given by a speaker, and there is good reason to believe that the ultimate information-input rate is not limited by either of the main human sensory organs, the eye or the ear, but only by neural mechanisms in the brain. [4B] What seems to happen if one sensory mode is being used efficiently is that other sensory modes are locked out to some degree. Furthermore, motivationally, and particularly with children, where a large part of their early learning experience has been via the television medium, there is an expectation that both senses will be used. Thus, a strong argument can be made for having two sensory modes available in educational media--the only question is the degree of correspondence to reality that is required to provide effective programming over a wide variety of subject matter, and learning needs and differences.

If we look at television, we find that we have high-fidelity (although monaural) audio available, and a relatively low-fidelity color picture, with motion capabilities. There are, of course, many instances where nothing less will do. This is particularly true where we must at least give the appearance of reality, and when we are dealing with situations which should be regarded as being live. However, for instructional purposes, these occasions are few and far between, and we can certainly forgo the immediacy criterion. In fact, if there is much information to be transmitted, it is essential for good retention that the material be repeated a number of times--perhaps with changes being made to sustain interest--but nevertheless this kind of reinforcement is instructionally very desirable.

TV for Instruction

Looking at the economics of the situation, the most severe media requirement is that of motion. If we are willing to sacrifice this capability, we can achieve an immediate saving of several hundred times in bandwidth, which we can then trade for versatility in terms of the number of different channels that can be made for available for approximately the same cost.

Thus, what we propose is taking the 6-MHz bandwidth required by a single television channel, and devoting it to a hundred different audio-visual channels, each capable of carrying one audio signal and a sequence of still pictures. We will call this educational satellite system EQUOPS. In fact, because we have essential broken the tight bond between sound and picture, we can use these channels in a number of combinations, such as audio only, stereo-audio, visual only, audio-visual, etc., as required by the educational objectives of a particular subject.

One way to divide up the utilization of this enormous bandwidth for a nationwide audio-visual communication satellite would be to devote some channels to scheduled programs of wide and continuing interest, and others to specialized services. The former type of programs would be repeated over and over according to predetermined frequency of use. Users would be made aware of the scheduling, both by printed materials, and by using one of the 100 channels* to announce what is coming up in the immediate future. Similarly, time zone and other local differences (such as language) could be easily taken care of, given the mulitiplicity of channels. Remaining channels could be used to transmit specialized instructional materials on-demand. Catalogs of such materials available on this basis would be frequently updated and widely disseminated.

The Nature of the Ground Equipment

Because we want to fully utilize existing closed-circuit television presently on the ground, such as cable and 2500 MHz, and in particular, the rather large capital investment presently devoted to television receivers, we conceive of the receiving part of the EQUOPS system as being completely compatible with these existing educational distribution systems. While no particular modification would be required for audio-only programs, certain additional hardware is essential to display the visual portion of the programming.

Because we are sacrificing motion in our A-V material, it is necessary that a means be provided to continuously regenerate the picture 30 times a second to feed the TV monitor until a change of picture is desired. We propose to accomplish this as much as possible with existing hardware and a number of approaches will be explored. For example, one method might be for a high quality nonprofessional multi-track audio tape recorder (or recorders) to receive EQUOPS signals. Each track stores an audio signal, or a (still) video signal, or a sequence of digital control signals.

At 7½ inches per second (the usual nonprofessional high fidelity recording speed), a single picture of television quality could be recorded in approximately 8 ft. of tape, each complete picture requiring a 12-second broadcast. However, 12 seconds would be far too long for a viewer to wait to see a complete picture; worse, without some means of storage, the lines of the picture would disappear just

* The exact number of channels available remains to be determined.

as fast as they are written. Thus, additional speed buffering is required to make the system feasible. This might be accomplished by transferring the tape-stored picture at local convenience to a magnetic disc system.

One promising device just coming on the market is the Panasonic "Video Sheet Recorder", which is capable of storing 450 different pictures(TV frames) on a 12"-diameter disc. Although detailed specifications of this device are not yet available, it appears that it can be used for recording either conventional television signals, which can be played back at normal or slow motion, sampled TV frames for stop-motion, or still pictures. Any of these can then be played back for display on unmodified television sets.

Because this video disc device is capable of storing and retrieving 450 picture frames on each recording disc, audio tape recorders may not be needed to store the pictures, but would probably be needed to record the sound to be associated with the pictures; it would merely be a matter of devising a control system to sychronize the sound track with a sequence of pictures. Such a system might use the techniques developed for sound-slide or filmstrip projectors, whereby an impulse is recorded on the same audio track, using a frequency outside hearing range, or on a separate track using audio tones or pulses, which trigger the changing of the picture in the slide or filmstrip projector. The only matter remaining is to insure that the device which is recording signals is not restricted to television input speeds. If not, then audiotape probably will be required as a intermediary buffer to receive and store the signals from the satellite. However, the problem remains of bringing this tape up to very high speed to couple to the disc, or slowing the disc down, or a combination of these.

In essence, the problem is one of taking a very slow speed picture and storing it so that it can be recycled rapidly for display on an ordinary television set. Because typical filmstrip presentations run 30 to 40 frames, each video disc can store approximately 10 such programs. While this may be enough for some instructional situations, many of the larger users will require more simultaneous programs, in which case it may be necessary to use several Video Sheet Recorders. A better solution would entail device specialization, so that one device does the recording from the satellite signal and several much-lower-cost devices are used to play the disc back. If these devices were low-cost, they could be incorporated into individual monitors, thus giving many school systems which to do not have closed-circuit TV access to this material at minimal cost. They would be using the television set virtually like a rear-screen projector, but with the great advantage that the usual manipulational problems of AV hardware would be by-passed, and with a considerable saving over having to have different display devices for each medium. Video technology provides a tent under which all media so far developed can be used.

So that the operational problems may be worked out in detail before EQUOPS is launched, it is highly desirable that a prototype system be put together at Washington University for use in local school situations, in conjunction with educational television station KETC (Channel 9). We will explore engagement of both city and county systems in this experiment. The city already has an educational radio system in use, which the Superintendent of Schools, Dr. William Kottmeyer, has used to great effect teaching spelling. It would be a natural step to see what could be gained, and what the problems are, in adding the visual element to a limited number of spelling instructional situations.

Furthermore, KETC could air some of the still-picture/sound combinations (which have been shown to be effective in filmstrip or slide form) during the school day, under carefully controlled conditions and with good evaluation techniques. Thus the first phase could be done without any of the specialized equipment by simply using a Telop (flying-spot scanner) system. Once this concept was shown to be educationally viable, we could proceed on to the next phase, which would entail the installation of a few disc recorders in school systems, and using late-night and early-morning hours to broadcast specialized materials on-demand to each of the participating school systems over ETV stations. The third phase would attempt the use of a multiplex FM channel to distribute these materials.

Thus, by an evolutionary process, we can prove out both the educational and operational advantages of this system over the next two years. If EQUOPS was to be launched during 1972, we would have a reasonable number of ground systems already in operation ready to make use of its signals.

By providing the satellite with bandwidth capability in multiples of a single television channel, we can use such channels for live television during the school day, and distribute audio and visual educational programs the rest of the time. This would be particularly good for current events, which could be explored to a much greater depth for student audiences than either a commercial or ETV network could be expected to provide.

Thus, what we are considering is not a substitute for educational television, but an entirely new and complementary service which can take advantage of a host of instructional material developed over many years to provide for much more specialized audiences and interests than is warranted by the usual economics of educational television. In a sense, the EQUOPS concept is half-way between television and radio, and we feel that it will fill this great void in a very significant manner.

As in other aspects of the EQUOPS system, the feedback aspects (of which ordering materials on-demand is just one phase) are expandable in easy stages. In the initial experiments on the system, there is no reason why regular ground communication channels cannot be used for ordering or feedback; however, if EQUOPS itself is to have feedback capabilities, major design differences will be necessary. In fact, the whole question of feedback is one that requires intensive study of its own to evaluate the technical, economic, social, and legal trade-offs anticipated during the satellite's life-time.

EQUOPS Step-by-Step

The first stage of development of this system would envision having ground transmitters at convenient locations. Of course, as in many other types of long-range communications, it is desirable to establish the physical transmitting equipment at some distance from production studios, for such reasons as land-use strictures and cost, and interference. However, it is also desirable that these distances be kept as short as possible.

One site in particular recommends itself for the first wave of transmitting ground stations, and that is the National Center For Audio Tapes at Boulder, Colorado, which now has approximately 12,000 audio-only productions available. They claim this is the largest collection of instructional materials in the country. Simiarly, other centers which have built up large stores of instructional materials, such as NET Headquarters, MPATI Headquarters, and several of the most advanced state education systems, should be considered as first-wave sites. Each of these sites would be provided with appropriate editing equipment to enable their materials to be converted to a form suitable for EQUOPS communications and storage. For example, material on films and videotapes would be edited in such a way that a sequence of still pictures would be drawn from the programs, and modified narrative developed to acocompany it. The reason that the Audio Tape Center is so attractive is that this one could use EQUOPS facilities without modification. Also, film strip and slide sequences could be sent using some type of flying-spot scanner. Thus, even in the early stages we anticipate having a number of sending stations, perhaps between 5 and 10, while, on the receiving end, we would want to involve perhaps a hundred school systems and community centers. These receiving locations would be picked on a careful stratified sample basis, to provide the maximum amount of data for evaluation. That is, a number of them should be located in major metropolitan areas, some in small cities and towns, and some in rural and remote locations. The latter will, of course, require special efforts of the part of the developers, as it is anticipated that necessary operational personnel will be particularly hard to locate in these remote areas. On-the-job training may be the answer in these cases.

The most desirable situation for the EQUOPS satellite would be a coverage extending over all of North America. Channels would be best assigned on the basis of school-age population (but with each country getting at least one audio and one visual channel). Therefore, special efforts might be made to develop a cooperative program with our neighbors Canada and Mexico. In any case, because of the nature of satellite communications coverage, it would be difficult or impossible to exclude signals from border portions of these countries. We think that EQUOPS provides a considerable stimulation to such cooperation, as we could offer both French and Spanish language material on a number of channels--material developed by Mexico and by Canada, for example. Obviously, this also would provide great advantages for U. S. foreign language instruction. In fact, having a great number of channels entirely changes the picture of satellite communications from one of a scarce resource to one of plenty. Thus, a great deal of experimentation can be done at low cost.

The feedback capability from the hundred centers would start off rather simply. What is required is a single point of entry into the system for all its customers, which would probably best be located in the middle of the United States. This station may or may not be associated with a transmitter or program material. It would however, contain a small to medium sized computer, and perform essentially a booking operation, whereby users would call up over the long-distance phone system, perhaps using the INWATS class of service. The computer would be coupled to an automatic voice-answerback system, and the whole process could thus be made completely automatic, except for exceptional cases, which would be handled by a resident AV expert.

This first-wave system centers on the widespread avilability of the Touch-Tone telephone to be used for both "dialing" and data entry. Thus, once the requestor has made connection with the computer he would key in the order number of the desired material, and the computer voice-answer-back system would respond with either a confirming date and time, or with a message of temporary unavailability.* The only additional action necessary on the customers' part would be to insure that they had their receiving system turned on prior to the proposed transmittal date for the materials. At the time of transmittal, the computer would see to it that the instructional material was put on the air at the appropriate time, and that a signal be transmitted just prior to this time, which would address the ground site or sites requesting the material. This would be done through well-developed telemetry techniques, and might eventually include both turning on the receiving set, and tuning it to the proper channel. In addition to this, because a number of other ground receivers might be desirous of getting the same material, announcements of the complete broadcast schedule, both of scheduled access and demand access, and last-minute changes, would be made available to all users through a facsimile channel.

It is believed that the most critical aspect of the system to be developed centers around the ground stations in school systems and community centers. Although we believe such a center could experimentally be put together with equipment presently on the market, over the long run certain types of specialized equipment might be developed especially for this system. Furthermore, it would certainly be necessary at most of

*More general question-capability could be added to the system later, such as providing special lists of available material in different subject areas.

these ground locations to have a resident AV expert, plus one or two technicans to handle the somewhat complex scheduling required locally (however, this is only the case if on-demand capability is desired). It is certainly true that if a ground system was made only for scheduled access--similar to the present ETV system--a technican could probably be trained to handle all local control requirements.

The system as a whole should be made as adaptive as possible to the changing needs and requirements of its customers, particularly in attempting to always optimize the use of the channel capacity (however, such channel-use optimization is less important by several orders of magnitude than would be the case with full-television capability). What we mean here is that when demand requests are few, that the system would take up the slack and fill the unused channels with more scheduled access materials. On the other hand, when demand was heavy, scheduled access would be cut down--but never brought below a certain minimum.

In summary, what we have is a system that takes on a hybrid character, somewhat between pure broadcasting and the switched telephone network. Hopefully, this would provide capabilities not now in existence.

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APPENDIX C

Preliminary Studies On The
Impact of EQUOPS On The
American Educational System

by

James R. DuMolin

1. INTRODUCTION

The inequalities of domestic education have, for the decade of the sixties, been a major focal point of dissatisfaction and unrest. In response there has been a tremendous expansion of educational facilities, and a concerted effort has been made to expand education on an equal opportunity basis. But educational deprivation is still chronic at the bottom of our nation's social structure. These groups have become dispossessed from the educational mainstream of the middle classes and are plagued by problems of sickness, broken families and mental illness.

The increasing spread of affluence in our nation as a whole has not decreased its social problems; however, it has increased demands to attack and eliminate existing social problems. The disenfranchised segments of our society have been seized by the "revolution of rising expectations" and are now demanding social, economic, and educational justice as part of achieving their share of our society's benefits.

Attention has been focused on the inability of American schools, both public and private, to educate the children of the poor. In hopes of finding possible solutions, educators and media specialists are combining their talents to develop new educational tools to help break the cycle of inadequate education in culturally deprived areas. The purpose of this paper is threefold; first, to discuss the basic problems involved in the development of relevant media material and to outline existing educational trends in its utilization; second, to propose a new and somewhat unique method for universal distribution of educational media via satellite on AN equal opportunity basis to all areas of educational need; and third, to discuss the impact of this new media-distribution system on both formal and non-formal education in the United States.

2. The Role Of Educational Media In The United States

In discussing the role of educational media, it is necessary to examine past experiences in the utilization of mass media and to study present trends in the use of media in the American educational system. By "educational system" we mean not only "formal" education (primary, secondary, and post secondary) but also "non-formal" processes, including special preschool education, on-the-job and in-service training, functional literacy classes, professional refresher courses, and special youth programs. These formal and nonformal educational activities collectively comprise the nation's total organized "educational system".

In discussing the term "new media" and its relevance to education, our concern lies in the various forms of television and programmed instruction, as well as a variety of devices such as motion pictures, sound tapes, film strips, micro-film and slides, all of which have been used for many years.

The new media in relation to education have three major functions: providing information, socialization, and mobilization (Janowitz and Street, 1966)*. The information function is the transmission and dissemination of information and essential knowledge, and the posing of alternative forms of economic, social, and political action. The socialization function is the communication of cultural norms and the transmission of values which orientate a person toward the proper modes of social interaction--from the family to the nation-state. The mobilization function is the process of persuasion and the development of loyalties and associations which are necessary for collective problem-solving.

* See bibliography at end of this Section.

The media functions of information, socialization and mobilization, as described, are socio-cultural in nature and differ greatly with the usually narrow stimulus - response models which center primarily on the structural aspects of the information function. Past studies have been mainly concerned with the immediate effects of media on classroom technique and the economic and organizational problems involved in its utilization. Questions are seldom asked about the long-term consequences of media, such as its impact on student interest, morale, values and social relations. There is little information on the effects of media on the teaching staff, student body, or the educational institution as a whole. In many cases these side effects of socialization and mobilization may be more important, more powerful, and more relevant to educational needs than the direct effects of simple information dissemination.

The impact of the new media on the education system must be examined in light of the social environment within which it must operate. In America this environment is dominantly urban and metropolitan in nature. It is characterized by a multitude of social and economic needs which, combined with a variety of cultural and ethnic backgrounds, challenge the American educational system.

The new media are being forced to adapt to the multiple social and personal capacities of the student body and at the same time offer a curriculum with enough diversity to satisfy the varied need of the urban occupational structure. In this regard, the media are being used to satisfy an increasingly heterogenous audience. On the other hand, society demands that the functions of the new media--information, socialization, and mobilization-equally stress symbolic values and content which are unifying and inclusive in nature and promote social needs and interactions. In general, the new media are "mass" by nature and emcompass a wide audience. It is, therefore, necessary that media maintain some common denominator in form and content. The true challenge in the development of relevant media is in maintaining the proper balance between the need for specialized content and the importance of stressing homogeneous and unifying symbolism.

To a great extent, the problems of specialization and homogeneity are reflected in the American educational format. The first of these formats is called "standardized" education, that is, the acquisition of uniform basic skills on a mass basis to meet everyday technical and social needs. The second format is "individualized" or "problem-solving" education which stresses the differential treatment of students for the higher development of both technical and personal discrimination skills. These skills are emphasized in the socialization and mobilization functions as opposed to the standardized format which stresses the information function.

There are those who feel that the rapid introduction of the new media, via satellite or traditional methods, will improportionately emphasize the standardized format to the neglect of the equally important individualization need. It is feared that the mass media in education will lead to uniform treatment of broad categories of students in routine and inflexible curricula.

It has been suggested that widespread distribution of media will promote an increase in the social stratification of the educational system. Given the economy and utility of using the new media in a relatively standardized format, there may develop a tendency toward a two-track system of education. Many of the poorer educational institutions (ghetto, rural and some private schools) are beginning to feel the "brain drain" of qualified staff to better financed and safer schools. As a result, many schools are supplementing their curriculums with standardized ETV materials, and because of lack of qualified teachers are sacrificing problem-solving orientation. The more affluent suburban schools that have the financial resources will supplement standardized curriculum with personnel and equipment to promote individualization.

If these trends continue, they may lead to the development of a rigid, two-track, European-style system: standardized versus problem-solving education. This would promote a social dichotomy between the "have" and "have not" institutions. The "have not" schools of the ghetto minority groups would be relegated to the utilization of standardized formats which are best suited to the production of technicians. The "have" schools with their greater financial resources would provide a problem-solving education for potentially creative elites in a special privileged setting (Janowitz and Street, 1966).

These eventualities are not inevitable. The problems associated with media expansion are not inherent to the media itself, the media per se do not introduce standardization. It is the way in which media are administered and distributed which increases centralization and inflexibility. The rest of this paper is devoted to the development of an administrative organization which uses advanced technological distribution methods to make media presentation flexible enough to overcome the present trend toward standardization.

3. Audio - Visual Satellite Instruction

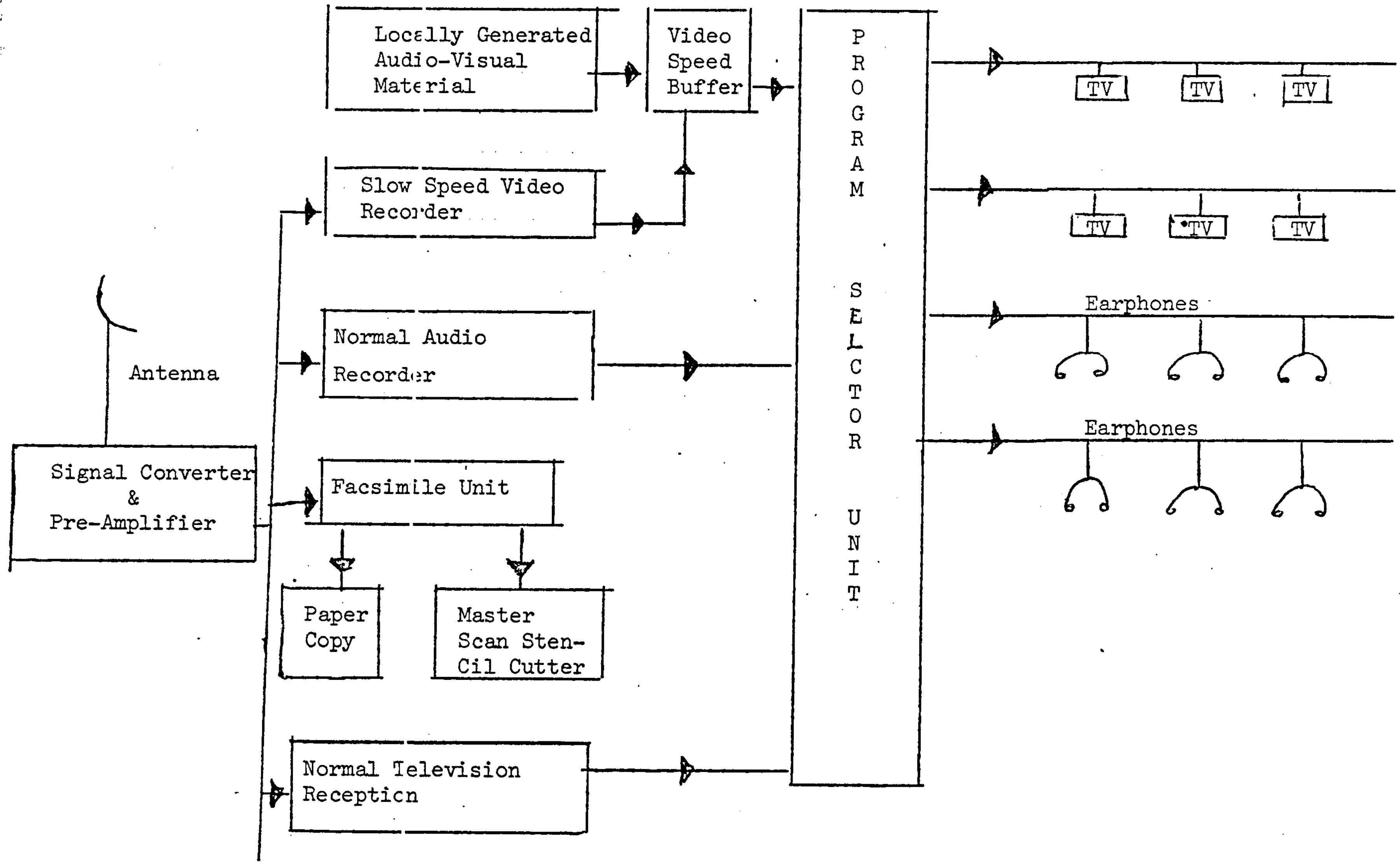
EQUOPS

The core of this program would be a multi-media instructional satellite. Technically, it would have the capability of broadcasting two hundred special audio or visual channels within a 10 MHz bandwidth spread to all fifty states and U. S. Trust Territories. The audio channels would be used for instructional radio, high fidelity music, or as sound tracks for the visual channels. Video channels would have the capacity to broadcast selected still pictures such as slides, film stripes, microfilm data and specially edited presentations of normal television and film programs. Video channels would utilize slow-speed broadcasting and recording techniques with lowcost storage and special playback facilities linked to unadapted normal television and earphone sets. The EQUOPS system would have the alternative capability to transmit and receive one full-motion normal television channel for instantaneous reception of special events.

Each school or community center would be equipped with a special antenna and signal converter. This would be linked to one to four, eight-track tape recorders, each with a capacity of simultaneously recording four A/V channels for a total of sixteen channels.

Figure 4 illustrates how slow-speed video signals are recorded, then transferred to a video speed buffer where they are modified into normal video still pictures for television use. These signals are then relayed to a program selector unit where they are coordinated with their audio counterpart and distributed to receiver sets via cable.

FIGURE -4 EQUIPS RECEIVING CENTER (ONE POSSIBLE CONFIGURATION)



Locally generated audio-visual media can be easily integrated into the EQUOPS system by passing slides, microfilm, and film strips through the speed buffer where they are modified into television signals for distribution. Local films can be linked by a film chain into the program selector and distributed simultaneously by television to the desired classrooms. Language tapes and music lessons would follow the same route as audio signals recorded from the satellite through the program selector for distribution to listening centers.

The EQUOPS system has the added advantage of being able to handle facsimile transmission over its A/V channels. In this way, supplementary printed matter (teachers guides, discussion questions, tests, etc.) can be distributed to the school along with the A/V instructional material. The facsimile unit can produce a single copy which can be reproduced on school equipment. The unit can be linked to a master scanner which will automatically cut a master ditto stencil.

The EQUOPS system has the alternative capability of receiving one normal-time, full-motion television signal in lieu of its two hundred* A/V channels. Scheduling between these two alternatives will depend on need and demand. There is very little audio-visual material which demands full-motion, real-time presentation. Most available instructional television material could easily be edited into still picture presentations without losing anything in quality or content. It is also quite feasible to broadcast, record, and store the desired selections from the two hundred audio-visual channels during the late night hours. This would free the system for normal television reception during the day.

Broadcasted materials would be made available in two ways--scheduled and demanded access. Scheduled access would include those materials that

*The exact number of channels remains to be determined.

are used on a day-to-day basis such as continuing courses in mathematics literacy, and music, or those items which have been shown to be in constant or high demand. Demand access would be available on a twenty-four hour, advanced request basis. Teachers or students would select programs of special or unique interest and telephone their requests to regional centers a day in advance of the time the material is required. Computers would automatically assign channel and broadcasting times and relay this information to the school in time for recording and storage.

The EQUOPS system can easily be adapted to schools which are already equipped with closed circuit television capability by simply interconnecting the EQUOPS program selector with existing equipment. Many institutions and school systems receive their television signal via cable or microwave from community ETV stations. These ETV stations could be equipped with a modified EQUOPS receiver and playback units large enough to manage the increased demand. In this way, EQUOPS would serve as an important addition source of material for existing large-scale ETV operations without extensive and expensive redesigning and replacement of equipment.

An essential part of the EQUOPS system would be a fully-equipped and well-staffed production and broadcasting center. These centers would be placed at major sources of audio-visual materials and have on hand access to large libraries of audio and video tapes, slides, and micro-film data. Broadcasting centers would also inclıde special editing departments where media experts would adapt presently available video tapes and motion pictures into multiple still picture programs with their appropriate sound tracks for distribution over the special A/V channels. Centers would be linked with the major news and TV networks so as to be able to supply via satellite special events such as space achievements and presidential addresses.

In total, the EQUOPS system provides the educator with an unparalleled access to vast stores of previously hard-to-obtain or undistributable educational material. It also supplies him with an instant, high-quality multi-media presentation system which can stand by itself or be easily integrated with existing systems. The utilization of space satellites gives the system the unique ability to universally distribute large quantities of instructional information to previously unreachable areas where the educational need is greatest.

The final section of this paper will outline the major problems in the utilization of the new media and illustrate EQUOPS capability to meet these problems in both the formal and nonformal educational context.

4. The Role Of EQUOPS In The Educational Process

In the American school system, the pressures for adoption of the new media have been strong and rapid, with little thought given to the resulting social consequences. Generally, it is only after media devices have been introduced that policy questions as to organization and administration have begun to be asked. The answers to these questions will determine if the new media are to be used to increase standardization, as described earlier, or are to contribute to individualized education. These questions will involve organizational control, curriculum flexibility, and professional standards. The introduction of EQUOPS will raise many of these same questions.

Two major trends have followed the introduction of the new media in school systems (Biddle and Rossi, 1966). Although there has been widespread introduction of media devices, they have been underutilized and closed off from students and teachers by compartmentalization. However, professional educators are beginning to seek new ways to present and organize media so as to overcome trends toward standarization.

"Token saturation" is the phrase coined (Janowitz and Street, 1966) to illustrate the situation resulting from powerful pressures for introductive use of the new media, opposed by equally strong restraints on its utilization. Token saturation and its result--underutilization--are often the reaction of administrators who have been pressured by school boards to innovate but are hoping to avoid undue disruption of their schools until effective administrative procedures are developed. Many times the professional rigidity of the teachers themselves leads to organizational sabotage of media projects. This reaction is generally due to lack of understanding by the teacher as to what role the media will play in his educational technique. Frequently, many teachers shun media devices because of lack of experience in the utilization and operation of the sometimes exceedingly complicated apparatus.

Many times media systems have built-in rigidities which make them unable to cope with the variable needs of large school systems. One of the reasons cited for the failure of the MPATI project was its inability to produce a flexible enough curriculum to meet the multiple needs of its users. In addition, many media systems make no allowance for remedial work by slower students or are incapable of handling the special needs of superior students. In short, administrative, professional, and technical problems have greatly hindered the effective utilization of the new media.

In response to token saturation and resistance on the part of administrators, educators have combined with scientists and technicians to develop adaptive solutions to overcome these problems raised in the application of new media. These solutions include: the restructuring of teaching tasks, programs for individual development, and the development of interpersonal feedback.

In the area of restructuring teaching tasks, it must be remembered that the media will at most play a modifying role and even under the best conditions never be able to replace the teacher. The media will act as a supplementary tool available for easy manipulation by the teacner at the right time. The teacher who has ready access to a variety of educational media--television, slides, audio tapes, etc.--will be able to orchestrate his teaching procedure so as to provide the most effective form of communication at the proper time.

The **EQUOPS** system is designed to make available to the teacher a vast storehouse of media material from which to satisfy his needs. Because of the easy availability of scheduled materials, which are recorded nightly, and the rapid, twenty-four access to specialized programming, the teacher is able to present instruction which is both creative and pertinent to the varied needs of his classes.

In addition, because **EQUOPS** material is prerecorded, the teacher previews materials before classroom presentation. **EQUOPS** facsimile unit would also provide written teachers guides and discussion questions to help prepare the teacher's presentation. **EQUOPS** is flexible enough to allow the teacher to articulate his personal needs, thus helping to avoid many of the problems of rigidity which lead to standardization of curriculum.

Of course, teachers will have to be trained in the proper methods of coordinating media materials for classroom use. However, the teacher's job will be simplified in that EQUOPS utilizes normal television receivers and earphones linked to the classroom by cable from the school's receiving center where a technican will coordinate the reception, recording, and replay of the material for the teacher. In this way, the teacher is not bothered by having to move his class to special viewing rooms or by having to waste time setting up and operating complicated projectors and slide machines. The technician, who may also be a media specialist, will act as cataloguer, librarian, supplier, and in-service trainer for the teachers. By making the physical presentation of media as easy as possible the EQUOPS system goes a long way to insuring its proper utilization.

The second response educators are making to combat standardization is in the area of designing media programs to meet the developmental needs of individual students. Attempts in this area have been frustrated by the very nature of the organized school system. The structure of the American educational cycle is one of the lock-step progression from one grade to the next according to chronological age, not mental ability. The use of media to educate large blocks of students in standard formats does not allow for individualized self-learning. The school should make it possible for the student to proceed beyond his grade level at his own speed or provide special assistance to help him overcome deficiencies. In response to this need, the EQUOPS system provides the individual student with much the same flexibility in choosing study materials as it does the teacher. EQUOPS' two hundred channels provide not only the standard curriculum of normal ETV instruction but also enough channel space to supply remedial programming for those who need it. Superior students with more advanced interest would be able, with the help of their teacher, to develop their own curriculum using the twenty-four hour demand access cabability of the **EQUOPS** system. Individualization is only limited to the number of television receivers and/or earphones in the classroom.

Another area of adaptive development has emphasized media presentations which avoid the loss of face-to-face interaction and feedback between students and teachers. Only if the teacher has personal contact with the student can he be sure that the material is relevant and accomplishing its task.

Media specialists claim that the utilization of audio-visual devices will mean the reallocation of time in such a manner as to provide more time for interpersonal contact with individual students. This they feel is especially true in large classes where interpersonal interaction has in the past been impractical. As a counterclaim, it has been argued that much of the teacher's newly freed time is taken up in the organization and coordination of media presentations. Studies are beginning to show that the great increase in teaching productivity resulting from the use of media is not the cause of freeing the teacher from his role as teacher but from increasing the teacher's capacity to mobilize more resources in such a way as to promote a higher degree of student interaction in the educational process. It has been found that the introduction of media actually forces the teacher to work harder in preparing and presenting classroom material. In this process it is the responsibility of the teacher to develop and maintain an effective system of interpersonal communications with students. The **EQUOPS** program provides the teacher with a system for multi-media presentations of varied and easily accesible materials but it is the responsibility of the teacher to coordinate student activities and the media materials for maximum effectiveness.

The effects of media on the personal self-esteem of the teacher is a highly important factor in promoting effective utilization and avoiding token acceptance. Some educators see the new media as a challenge to their classroom authority. They feel that their position is weakened by the intrusion of outside experts via the television screen. This view neglects the fact that, with the introduction of media, the teacher's role is transformed from that of an authoritarian to one of a professional coordinator of expert personnel and resources. By providing the greatest possible variety of high quality programming, the EQUOPS system increases the professionalization of teachers by increasing their productivity and effectiviness, which in the long run will bring higher salaries and greater prestige.

To the American youth, the school system is the central focus of his daily life. Outside of the family, the school is the most important institution in a youth's cultural socialization. In the school the youth learns responsibility and begins to assimilate citizenship experience by emulating the examples set by teachers and administrators. The utilization of the new media play as important part in setting the scene for educational socialization. Media may be mismanaged in such a way as to weaken citizen ship training by reducing the competence and authority of the teacher or by increasing standardization. If this results, the student will lack a respectable model to emulate and, especially in the case of ghetto schools with minority group students, will feel his educational experience is irrelevant to his everyday life and needs. However, if the new media are used as outlined in the EQUOPS program, teachers and administrators will have enough flexibility to express education with effective competence and automomy. If the student feels the educational institution is providing him with an equal learning opportunity and individualized attention to his special needs, he is being appropriately prepared for participation in a democracy.

The preceding sections of this paper have illustrated EQUOPS' capacity to solve many of the problems concerned with the adoption and utilization of the new media in the formal educational context. It is now time to examine EQUOPS' ability to satisfy those specialized educational needs of the disadvantaged sectors of our society.

Many segments of population are grouped in physically or politically inaccessible areas where state and federal development programs are unable to reach or motivate them. By utilizing a satellite as the distribution mode, the EQUOPS system provides its instructional material on an equal opportunity basis to any user with the desire to tune in. Hopefully the basic reception unit, under mass production, would be available at between $1000 and $1500. This is well within the price range of even the poorest schools, public or private, and even local community centers. Utilization of the material via satellite would be completely voluntary and, as a result, free of many of the political and financial problems surrounding cable and broadcasting distribution methods. The EQUOPS system can reach widely dispersed groups such as migrant workers, Mexican-Americans, penal institutions, rural poor and also, because of its vast channel capacity, provide these groups with specially programmed material to meet their varied cultural and educational needs.

When using the new media to educate culturally deprived groups, certain unique advantages and disadvantages become apparent. A review of the literature concerning media and the culturally deprived will help outline some of the problems involved (Wade and Jablonsky, 1966).

It has been found that media are useful in extending frames of reference and in providing models and motivation for the disadvantaged. A study of ETV's effect on 1600 Negro children in a Free Schools project in Prince Edward County, Virginia, showed that school presentations of television programming and motion pictures served as important cultural events for these children because local theaters were segreated ("Action Program For The Disadvantaged, 1965"). A special program called "Roundabout" for disadvanataged preschoolers in Washington, D. C. revealed that TV characters-nonteachers and non-professionals--can and do serve as effective models for children to emulate (Mayirki, 1966).

Teachers participating in a New York public school project found that the effects of audio-visual instruction on students included increased attention, greater willingness to practice oral communication skills, and increased student question-and-answer exchanges in the classroom (Morrison, 1967). In a similar project where maximum flexibility and supply of media materials was made available, high teacher turnover dropped, student attendance increased, and disciplinary problems decreased. In addition, both teacher and student morale were high (Dubrowsy and Fornear, 1967).

These project studies point out the advantage of using media to provide disadvantaged students with a useful model to emulate and media's ability to help motivate students toward greater participation in the educational process. In urban ghetto schools where the dropout rate is close to fifty percent, the extensive utilization of media could serve as a powerful force in motivating students to continue their education.

However, teachers in these projects noted two serious problems: first, many excellent programs were wasted because teachers were not able prepare supplementary pre-presentation and follow up materials; and second, many of the programs were irrelevant to the students' needs, learning styles, and life experiences. In response to these needs the EQUOPS system was designed to prerecord instructional material in such a way as to make it easy for the teachers to preview material before classroom presentation. During the previewing process, the teacher can prepare additional materials and edit the presentations to meet the specific needs and learning styles of his students. In this way, extraneous or irrelevant materials can be deleted before they reach the classroom.

When multi-media material are made easily available, as with the EQUOPS system, students feel a sense of reality and self-determination in learning to learn. In many cases, this offers the student an escape from what he feels is the inertia of the self-contained supervised classroom. In total, these studies appear to demonstrate media's ability to reach disadvantaged students more effectively than traditional printed material. The media can continue in this role until the student is prepared and motivated to make the transfer from audio-visual materials to the symbolic printed form. The EQUOPS system may be the means of closing the gap.

In addition to their value to disadvantaged school children, audio-visual presentations have been shown to be effective in large-scale experiments in adult literacy training (Pierson, et al., 1961). The project, conducted in Northern Alabama, involved six hundred students over forty years of age and emphasized practical application of literacy skills such as check writing, street sign reading, and phone dialing. Comparison testing showed that television used in small group viewing centers with the help of a proctor (not necessarily a skilled teacher) was as successful as direct teaching, in the ares of word knowledge and word discrimination. The results of this project help point out the value of establishing media centers for supplementary non-formal adult education programs. There are about ten million functional illiterates in the United States who could be reached by EQUOPS programs in local community centers. These facilities could be used to provide evening courses in small business management, agricultural projects, secretarial skills, etc., to those people who work during the day or are beyond normal school age.

Viewing centers in schools or community centers, equipped with EQUOPS, appear to be the solution to reaching many disadvantaged groups. A study to assess the possiblity of using ETV to reach Spanish-speaking families in the Southwest showed that special Spanish-language programs failed to reach 60% of the study group (Schenkkan and Millard, 1965). Follow-up studies showed that many Mexican-American families did not have properly functioning TV sets; had less leisure time to watch TV; and in the case of large families, watching preferences were often in conflict.

In many cases, varying ethnic and cultural groups have different viewing habits and preferences. The results of a study of black and white TV preferences hypochisize the following: 1)blacks do not identify with programs which are family centered because these cohesive social units, as portrayed by TV, are not reflected in their everyday life; twenty-one programs highly rated by blacks emphasized conflict; and 3) that physical action is preferred by blacks who do not have a strong "oral culture" (Carey, 1966).

This data is important because it helps illustrate that most TV programming is irrelevant to blacks and poor minorities because it is out of touch with the reality of city life. It is necessary to develop programming on subjects relevant to the needs of the poor such as legal aid information, low cost budgeting plans, child health care, etc., and then presenting the information in the proper socio-cultural context. The problem is one of providing needed information to people who are not normally information seekers and who are not members of any organized unit such as the school classroom. One possible solution would be the use of EQUOPS to distribute needed information to block committees headed by local volunteers, social workers, or even VISTA members. It may be possible for these block committees to organize special information courses where EQUOPS would provide the bulk of the instructional material.

In summary it can be said that the new media, as implimented through the EQUOPS system, are capable of both reaching and motivating many previously inaccessable minority and disadvantaged groups.. However it is obvious that extensive work is needed in the development of organizational and administrative procedures to compliment the technical advancements in information distribution.

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APPENDIX D

Washington University "Gunn Effect" Activity

by F. J. Rosenbaum

I. Research Into "Gunn Effect" Devices

Before devices based on the Gunn effect, the direct generation of microwave power from dc in certain bulk semiconductors, can be used in low cost, high performance applications, such as satellite direct broadcast receivers, several aspects of their operation and control must be understood.

A. Local Oscillators for Receiver

If educational satellite link frequencies are ultimately assigned in the microwave range, some means of receiving the microwave carrier and detecting its information will be required. A very sensitive, low noise technique for this purpose involves mixing the incoming signal with a fixed frequency local oscillator (L.O.) so that a constant beat frequency (intermediate frequency or IF) is produced. The IF can then be amplified and detected. This process is called superhetrodyne detection.

Basic to the process is the L.O.. Gunn effect L.O.s have been built in coaxial, waveguide, and microstrip geometries. In the Microwave Solid-State Laboratory of Washington University we have been working on waveguide cavity CW oscillators for the past 30 months. We can now predict the oscillation frequency of a given microwave oscillator from geometric considerations and knowledge of the Gunn device physical characteristics. Its stability, frequency tunability and power output are now well understood. Its noise performance and the role of the external circuit are less well in hand and require addtional work.

In order to reduce manufacturing costs to accomodate the eventual mass market for such solid-state satellite receivers, we now need to study the operation of low power L.O. design in microstrip geometries. The waveguide and microstrip oscillators are similar in principle, but numerous detailed questions remain open. What in the noise performance of microstrip oscillators? How badly does the noise performance degrade in the inherently low Q microstrip geometry? Can the design of other receiver elements (mixers, filters, etc) be modified to optimize an integrated low noise receiver compatible with a microstrip oscillator?

One of our program goals is to establish a modest microwave integrated circuit facility where our own designs can be built and evaluated. A major portion of the funding required for such a facility is now in hand and it is expected that only a minor contribution from NASA would be required for its completion.

B. Microstrip Receiver

A detailed literature search in the area of microstrip integrated receivers will be undertaken. We wish to begin development of standard microstrip components such as directional couplers, mixers, power splitters, etc. in order to reproduce the state-of-the-art and to gain insight into the problems and potentials of these techniques. As we gain experience a simple receiver will be designed, constructed and evaluated. The design will be compatible with the demodulation requirements of the Multi-Channel, Low Frame-Rate Video system described in section C. From such studies the reality of proposed microwave integrated circuit receivers can be assessed in technical and economic terms more knowledgeably than is now possible.

C. Gunn Effect Amplifiers

Because of the enormous down link transmission losses ($\sim$120 db) it may be necessary or desireable to provide a stage of low noise pre-amplification at the input of the receiver. The Gunn effect can again be used for this purpose.

We are currently studying the properties of circuit stabilized, critically doped, Gunn amplifiers in waveguide. From our previous CW oscillator studies we have developed a detailed understanding of the effects of the microwave circuit external to the device itself. This means that we are able to characterize the semiconductor devices in these circuits and hence control their performance.

Our goals in this work are to identify the physical properties of the Gunn devices which will optimize the performance of the amplifier and to design, construct, and test broad-band, low noise amplifiers. Again, a study of the instantaneous bandwidth required for an amplifier compatible with our receiver deisgn, and the possible noise performance over such a bandwidth must be made. Extension to microstrip is again necessary to determine whether a fully integrated receiver can be economically achieved.

II. Washington University Gunn Effect Publications.

The Microwave Solid-State Laboratory has been active in Gunn Effect research for the last three years and has developed a national reputation for its work in the field. Included here is the program of a recent specialists conference sponsored by The Institute of Electrical and Electronics Engineers and held at Washington University. In addition selected recent publications are also included to demonstrate the scope of our program.

ST. LOUIS WORKSHOP ON GaAs MICROWAVE DEVICES

January 21-22, 1970

Cupples Hall II, Room 215
Washington University
St. Louis, Missouri

Conference Coordinators: J. A. Copeland, Bell Telephone Labs
L. F. Eastman, Cornell University

Local Chairman: F. J. Rosenbaum, Washington University

Wednesday Morning, 9:00 a.m.

Introduction and Welcoming from Washington University

Talks:

"Effect of Deep-Level Impurities on Bulk GaAs Devices"
John A. Copeland
Bell Telephone Laboratories, Murray Hill, New Jersey

"Device Material Impurity Characterization Using Photoconductivity Measurements"
W. C. Niehaus
Bell Telephone Laboratories, Murray Hill, New Jersey

"Photoluminescence Characterization of Liquid Epitaxial GaAs"
T. O. Yep
Varian Associates, Palo Alto, California

"Prove Method of Measuring Mobility and Carrier Density"
A. H. Thompson
Stanford University, Stanford, California

"Material and Device Characterisation for Domain Mode Oscillators in the Band 26 - 40 GHz"
D. J. Colliver
Royal Radar Establishment, Malvern, England

"The Effect of $AsCl_3$ Concentration on Impurity Incorporation in Vapor-Grown n-GaAs"
B. Cairns
Fairchild Semiconductor, Palo Alto, California

"The Effects of O_2 in an $AsCl_3$, Ga, H_2 Vapor Epitaxy System"
W. A. Johnson
Bell Telephone Laboratories, Murray Hill, New Jersey

Wednesday Morning, 9:00 a.m. (Cont'd)

"Effects of the $AsCl_3$ Mole Fraction on Undoped Vapor Phase Epitaxial Layers of GaAs"
G. E. Moore, Jr. and J. V. DiLorenzo
Bell Telephone Laboratories, Murray Hill, New Jersey

"Crystal Etch Monitoring by Internal Reflection Inteferometry"
D. L. Rode and W. A. Johnson
Bell Telephone Laboratories, Murray Hill, New Jersey

Wednesday Afternoon, 2:00 p.m.

Talks:

"Liquid Phase Epitaxial Growth of Multi-Layer GaAs Structures"
L. R. Dawson
Bell Telephone Laboratories, Murray Hill, New Jersey

"Effect of Solution Growth Process on Gunn Oscillators with Sandwich Structure"
Masatoshi Migitaka
Central Res. Lab, Hitachi, Tokyo, Japan

"Liquid-Phase Growth of Epitaxial GaAs for LSA Devices"
J. W. Monroe
Cornell University, Ithaca, New York

"Growth of GaAs by Liquid-Phase Epitaxy"
J. H. Higgins
Stanford University, Stanford, California

"Steady State, Temperature Gradient Solution Growth of Epitaxial GaAs"
David W. Woodard
Cayuga Associates, Inc., Ithaca, New York

"High Peak Power LSA Operation from Epitaxial GaAs"
Sven Christensson
Cayuga Associates, Inc., Ithaca, New York

"High Average Power Gunn Diode Operation and Construction"
Joseph S. Bravman
Cornell University, Ithaca, New York

Wednesday Afternoon, 2:00 p.m. (Cont'd)

"Experimental Study of FM Noise in Gunn Effect Oscillators"
M. Omori and F. B. Fank
Varian Associates, Palo Alto, California

"The FM Noise Spectrum of a CW Gunn Oscillator"
A. A. Sweet
Monsanto Company, St. Louis, Missouri

Thursday Morning, 9:00 a.m.

Talks:

"Transit Time Negative Resistance in GaAs Bulk Effect"
S. P. Yu, W. Tantraporn, and J. D. Young
General Electric, Schenectady, New York

"On the Stability Criterion for Gunn Devices"
R. Engelmann, H. Pollmann, and W. Heinle
AEG-TELEFUNKEN, Ulm, Germany

"Bulk Pulsed n-GaAs Oscillators with 25% Efficiency"
A. J. Shuskus
United Aircraft Res. Lab, East Hartford, Connecticut

"The Effects of Intervalley Scattering, Accumulation Layers and Domain Growth upon the LSA Mode"
J. J. Purcell and W. R. Curtice
University of Michigan, Ann Arbor, Michigan

"Pulsed Gunn Effect Power Amplification"
M. E. Hines
Microwave Associates, Inc., Burlington, Massachusetts

"Circuit Stabilized Transferred Electron Amplifiers"
B. E. Berson
RCA Laboratories, Princeton, New Jersey

"Second-Harmonic Characteristics of Wave-Guide Cavity CW Gunn Oscillators"
Y. S. Wu and F. J. Rosenbaum
Washington University, St. Louis, Missouri

"Numerical Simulation of Gunn Oscillator Operation"
H. Hummel and F. J. Rosenbaum
Washington University, St. Louis, Missouri

Thursday Morning, 9:00 a.m. (Cont'd)

"Encapsulation Effects on C.W. Gunn Diodes for Q- and J-Bands"
B. C. Taylor
Royal Radar Establishment, Malvern, England

"Diode Impedance Measurement by Network Analyzer"
M. Omori and F. B. Fank
Varian Associates, Palo Alto, California

"Temperature Effects in Gunn Diodes"
L. A. MacKenzie
Monsanto Company, St. Louis, Missouri

Thursday Afternoon, 2:00 p.m.

Talks:

"GaAs Device Research at Thomson-CSF"
A. deBouard
Thomson-CSF, Orsay, France

"LSA Oscillators"
M. Shyam
Fairchild Semiconductor, Palo Alto, California

"Observation of Fundamental Oscillations at Millimeter Wave Frequencies"
J. S. Barrera
Hewlett Packard, Palo Alto, California

"High Efficiency at Low Bias with Gunn Oscillators"
A. Mircea
Laboratoire E.R.G., Suresnes, France

"Further Study of Computer Simulations of Near LSA GaAs Oscillations"
W. O. Camp, Jr.
Cornell University, Ithaca, New York

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pp. 2164-2165

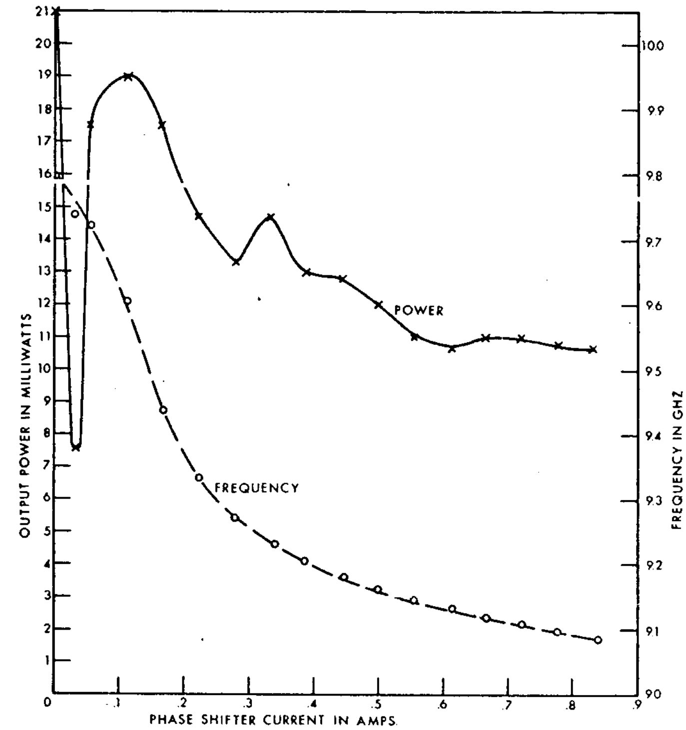

Fig. 2. Output power and frequency of oscillation versus magnetizing coil current.

Gunn Effect Swept Frequency Oscillator

***Abstract*—An *X*-band swept frequency oscillator using a Gunn diode and a ferrite phase shifter is described. Sweep widths of 800 MHz and sweep rates up to 400 Hz with less than 3 dB power variation have been obtained.**

Electronic frequency tuning of Gunn oscillators has been reported using a variety of techniques including varying the device bias voltage [1]-[6] and changing the effective electrical dimensions of the microwave circuit using varactors [7]-[9] or ferrites [10], [11]. The magnetically tuned circuits generally require large bias fields to obtain a significant tuning range.

In this letter we report an electronically swept *X*-band oscillator [12] employing a Gunn diode and a ferrite phase shifter as shown in Fig. 1. The frequency of a Gunn oscillator operated in a resonant cavity is determined largely by the cavity dimensions. In this device the diode is mounted on a cylindrical post which acts as one wall of the cavity. The length of the cavity is varied by sweeping the microwave phase shift. Sweep widths up to 800 MHz centered at 9.4 GHz have been observed with sweep rates up to 400 Hz.

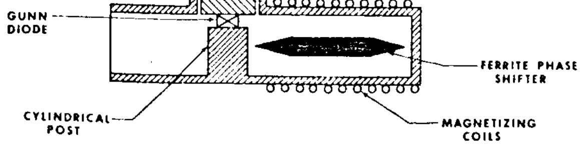

Fig. 1 Cross-sectional view of swept Gunn effect oscillator.

The frequency and power output of the sweeper are plotted in Fig. 2 as a function of magnetizing current. The magnetizing field was calibrated at 120 G/A. The Gunn device was operated CW with $V_b = 9$ volts and $I_b = 470$ mA. An oscilloscope photograph of a 640 MHz sweep from 9.74 to 9.10 GHz appears in Fig. 3. The power output and shape of the response may be adjusted with tuning stubs.

At zero current the electrical length of the cavity, and hence the resonant frequency, is established by the insertion phase of the ferrite phase shifter. Let the total insertion phase $\phi(i, f)$ be a function of magnetizing current and frequency, at resonance $\phi = n\pi$. The phase shift introduced by an increment of current Δi must be compensated by a frequency shift in order to maintain the resonance condition, that is,

$$\Delta\phi = \frac{\partial\phi}{\partial i}\Delta i + \frac{\partial\phi}{\partial f}\Delta f = 0 \tag{1}$$

or

$$f - f_0 = \frac{-\left.\dfrac{\partial\phi}{\partial i}\right|_{f=f_0}}{\left.\dfrac{\partial\phi}{\partial f}\right|_{i=i_0}}(i - i_0). \tag{2}$$

Manuscript received August 5, 1968. This work was supported in part by NASA Grant NLG-86-008-006 to Washington University, St. Louis, Mo.

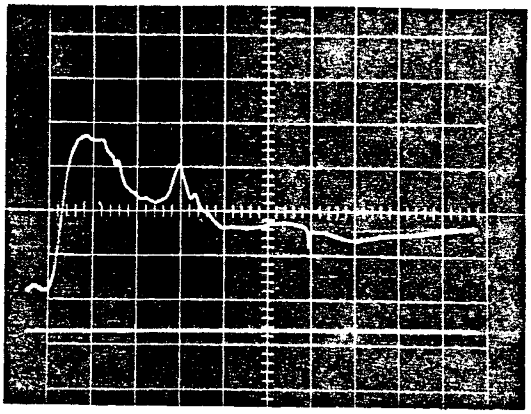

Fig. 3. Oscilloscope photograph of swept output power versus coil current.

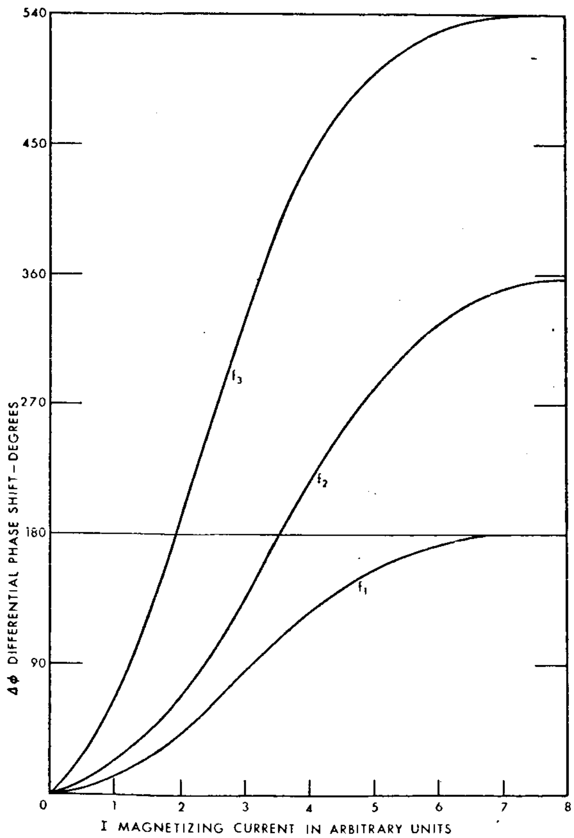

Fig. 4. Characteristic behavior of Reggia-Spencer ferrite phase shifters.

The characteristics of the type of phase shifter used in these experiments [13] are shown in Fig. 4, where $f_3 > f_2 > f_1$. As indicated by (2), the resonant frequency decreases with increasing current. The swept bandwidth will be limited by the frequency at which 180° of current saturated phase shift is obtained. At high current levels $\partial\phi/\partial i \simeq 0$, and so the frequency tuning saturates as seen in Fig. 2.

The results presented here are preliminary and do not represent optimized performance. A low to high frequency sweep may be obtained by properly shaping the magnetizing current waveform. The use of a latched ferrite phase shifter could provide tunable single frequency operation without the necessity of supplying holding current to the magnetizing coils. Frequency markers could be obtained by pulsing the Gunn diode bias voltage.

The use of a ferrite phase shifter in the Gunn oscillator cavity produces wide-band tuning with low applied magnetic fields. This approach may find useful system applications where a simple, compact, inexpensive swept microwave source is required.

ACKNOWLEDGMENT

The authors wish to thank Prof. R. O. Gregory for his assistance, and the Monsanto Company for their continuing interest in this work.

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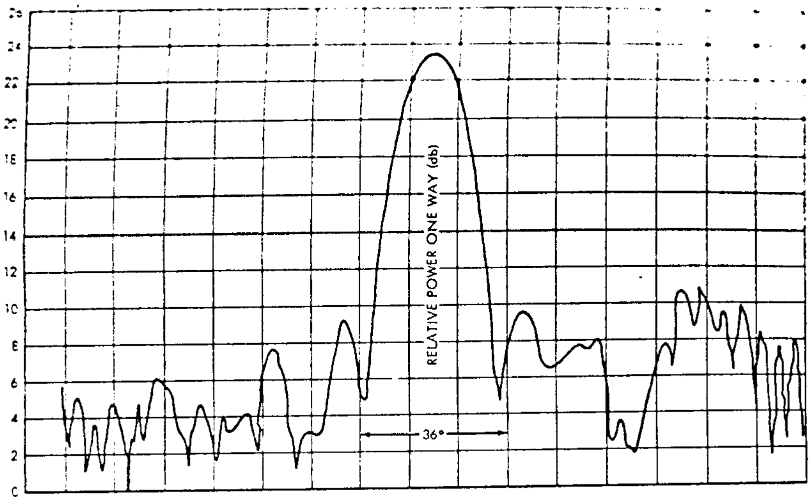

OUR ELEMENT FAR FIELD TRANSMIT PATTERN IN THE E PLANE, GUNN DIODES PHASE LOCKED

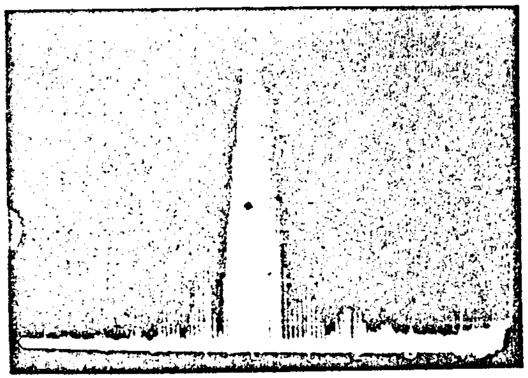

FIGURE 5

Spectrum of four element array phase locked to the same signal as measured in the far field

AMPLITUDE AND FREQUENCY MODULATION OF CW GUNN OSCILLATORS

Wei-Ching Tsai and Fred J. Rosenbaum
Washington University

The use of Gunn oscillators in CW Doppler radar, as local oscillators, and in other system applications often requires automatic frequency and/or phase control, frequency modulation or amplitude modulation. The frequency modulation of CW Gunn oscillators by simultaneously applying ac and dc bias voltages has been described by King and Wasse,[1] who discussed possible modulation mechanisms. Hobson[2] has reported an experimental study of voltage tuning using a biconical cavity.

In this paper we present the results of a theoretical and experimental study of AM, FM and AFC of wide-band tunable Gunn oscillators operating in the X-band. The oscillators consist of a Gunn diode mounted on a post in rectangular waveguide. The circuit is loaded with an iris and is tuned over the band with a sliding short located behind the post. The output power as a function of frequency is shown in Fig. 1 for a typical oscillator.

The devices used were epitaxial sandwich structures with an active layer length of L = 10 microns (nominal) and a doping density-length product $nL \approx 8 \times 10^{14}\ cm^{-2}$. When biased at 2-3 times threshold their transit time frequency is calculated to be approximately 12 GHz. From this result and from the experimental tuning characteristics it was concluded that the devices were operating in the delayed domain mode.[3,4] The device negative resistance matches itself to the positive load resistance of the microwave circuit while the device reactance is tuned out by the circuit reactance, thus establishing the oscillation frequency.

The device reactance has three components; the package capacitance and lead inductance; the domain capacitance; and the reactance due to the non-linear current-voltage characteristic. The package reactance is independent of bias voltage. The domain capacitance will be a minor contribution to the total reactance if the period T of the oscillation frequency is much larger than the dielectric relaxation time constant τ, i.e. $T >> \tau \simeq 4 \times 10^{-12}$ sec. This condition also implies that the static i-v characteristic can be used to calculate both the negative resistance and the reactance. It is this bias voltage controlled reactance which is responsible for voltage tuning of the oscillation frequency.

Since the device is situated in a resonant circuit the amount of voltage tuning obtained will depend on the circuit impedance and its loaded Q. For a fixed tuned circuit if the device suscep-

NOTES

tance changes by an amount ΔB, a frequency shift Δf will occur in order to maintain the resonance condition. This frequency shift is given by

$$\Delta f = \frac{-f}{2Q_L} \frac{\Delta B}{G} \qquad (1)$$

where f is the original oscillation frequency, Q_L is the circuit loaded Q and G is the load conductance seen by the device. For the X-band circuit previously described, the frequency and power deviation per volt change in bias voltage are plotted in Fig. 2 as a function of oscillation frequency. Also plotted in this figure is the reciprocal of the loaded Q as determined by measuring the maximum injection phase-locking bandwidth[5].

The loaded Q is a significant factor in both the AM and FM characteristics of the oscillator. Notice in Fig. 2 that the modulation sensitivity $\Delta f/\Delta v$ increases with increasing Q_L^{-1}. However, the power deviation per volt which is a measure of amplitude modulation decreases with increasing Q_L^{-1}. Thus in specific applications such as FM transmission, a heavily loaded circuit should be used to obtain high modulation sensitivity. Furthermore, when the oscillator is operated with an imperfect bias supply (dc with ripple and random noise), more AM noise will be generated in lightly loaded circuits and more FM noise in heavily loaded circuits. The scattering in the experimental points is due to parasitic resonances which are also apparent in Fig. 1.

As a first approximation, in order to obtain quantitative results, the effect of the iris is neglected and the real part of the load is taken as proportional to Y_o, the characteristic admittance of the matched waveguide. The factor f/Y_oQ_L of Eq. (1) is plotted in Fig. 3, normalized to the experimental modulation sensitivity of Fig. 2, at the point f = 9.4 GHz. At the lower frequencies f/Y_oQ_L seems to govern the sensitivity. However, at the higher frequencies this is not the case. The large difference in slope occurs because the device susceptance is frequency dependent.

Figure 4 shows the oscillation frequency plotted as a function of sliding short position. Also shown is the resonant frequency of the circuit when an empty device package is used as well as the theoretical result for the resonant frequency of a rectangular waveguide cavity operating in the TE_{102} with dimensions a = 0.9 inches and d = length. This frequency is given by

$$f = c \left[\left(\frac{1}{d}\right)^2 + \left(\frac{1}{2a}\right)^2 \right]^{1/2} \qquad (2)$$

where c is the speed of light. At the lower frequencies (large d) the oscillation frequency is offset by a difference Δf from the empty device package plus circuit resonance. From Eq. (1) this would require a device electronic capacitance of approximately 0.15 pf. This value is in reasonable agreement with theoretical calculations based on a physical model for the Gunn effect. At the higher frequencies the oscillator deviates from the empty package results because of the additional series inductance present when an actual device is used.

At the higher frequencies less voltage is required to drive the device to obtain a given deviation ratio, $\delta = f_d\,(max)/f_m$ where f_d is the frequency deviation and f_m is the modulation frequency. Thus the linearity of frequency modulation should be better in the more heavily loaded circuit. This is demonstrated experimentally in Fig. 5. Generally, these devices show higher frequency deviation per volt at lower values of bias voltage.

The frequency sensitivity to voltage noted in Fig. 2 can be used for AFC of the Gunn oscillator. An AFC loop consisting of a crystal controlled oscillator and multiplier chain, a mixer, IF amplifier, limiter, discriminator and an error signal current amplifier was constructed. With the loop closed the long term thermal drift of the oscillator was reduced to the same order of magnitude as the stability of the crystal oscillator. The short term random noise was greatly reduced. Figure 6 compares the oscillator spectrum with the loop opened and closed. The photos were taken with 5kc/cm dispersion and a 5 second exposure time. The oscillation frequency was 9.701 GHz.

ACKNOWLEDGEMENT

The authors wish to thank NASA for partial support of the work under grant NGL-26-008-006 to Washington University. The continuing interest of the Monsanto Company in this work is also appreciated.

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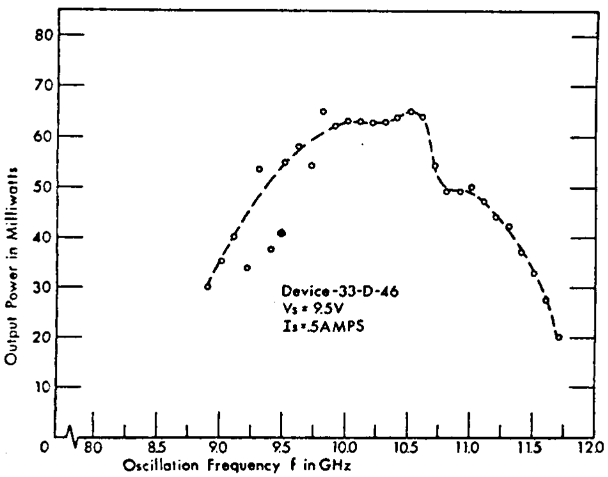


Fig. 1 - Output power as a function of frequency for X-band tunable oscillator.

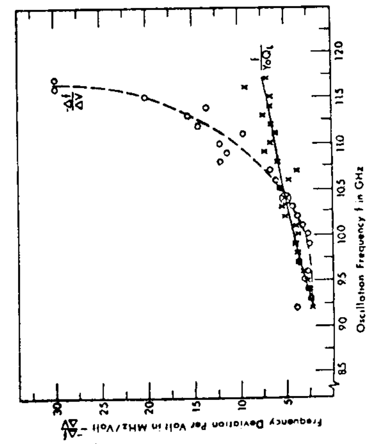


Fig. 3 - Frequency dependence of modulation sensitivity and normalized factor f/Y_oQ_L.

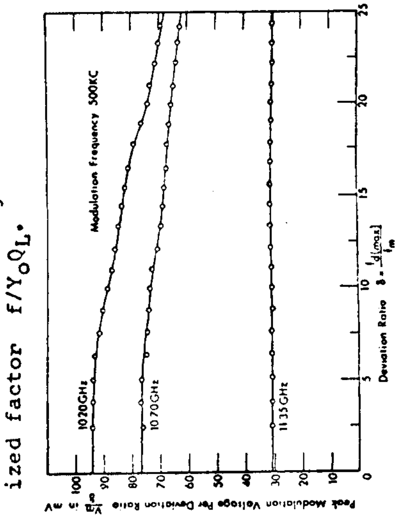


Fig. 5 - FM Linearity.

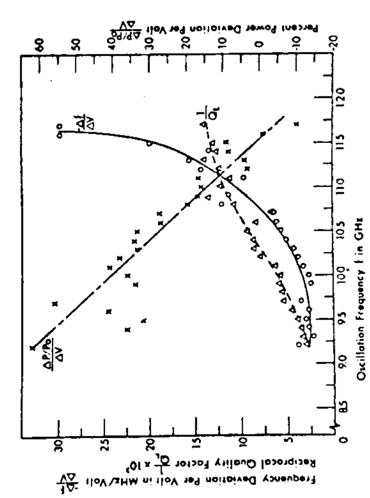


Fig. 2 - Modulation sensitivity, reciprocal loaded Q, and percent power deviation as a function of frequency.

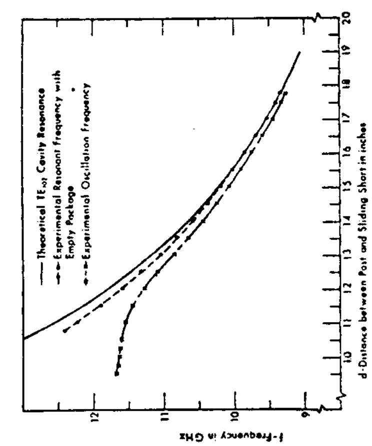
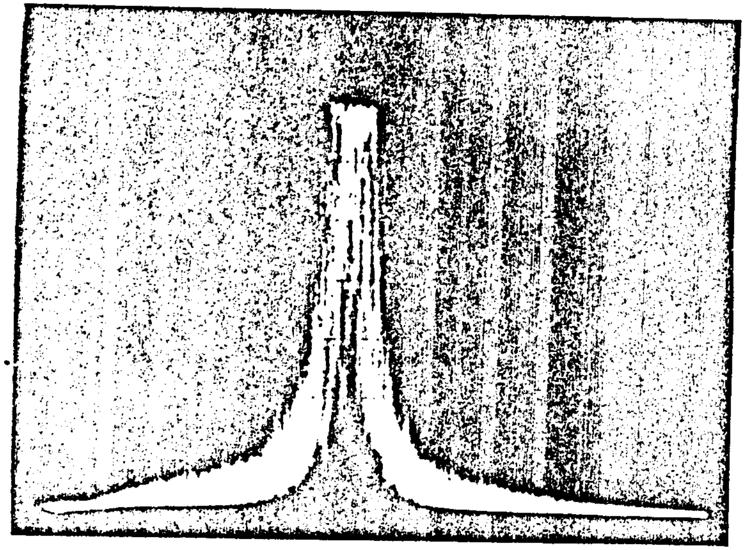
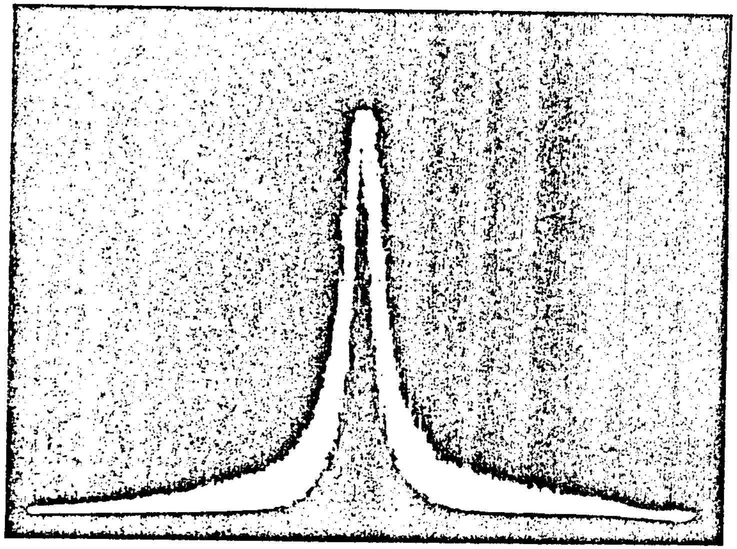


Fig. 4 - Oscillation frequency and circuit resonant frequency with empty device package as a function of cavity length.



(a) Free running spectrum



(b) Spectrum with AFC on

Fig. 6 - Spectrum of Gunn Oscillator. Disperision: 5 kc/cm.

Session : AM-II *Tuesday, May 6*

MILLI IETER WAVE COMPONENTS

Ch zirman: D. D. King

PRESENTED AT THE 1969 NEC (Dec 10, 1969) CHICAGO, ILLINOIS

MICROWAVE CIRCUIT DESIGN FOR WIDE-BAND TUNABLE GUNN EFFECT OSCILLATORS

Fred J. Rosenbaum

Electrical Engineering Department
Washington University
St. Louis, Missouri

INTRODUCTION

In the brief period since J. B. Gunn first reported coherent current oscillations in long samples of GaAs[1], microwave oscillators based on the Gunn effect have moved from laboratory experiments into commercial application. Two terminal packaged devices, called Gunn diodes, are being offered by several manufacturers. Complete oscillators in waveguide, coaxial, or microstrip circuits also can be obtained. The operating frequency, output power, efficiency, noise performance and temperature stability of these oscillators are largely determined by the microwave circuit presented to the GaAs chip terminals. It is the purpose of this paper to discuss the effects of the microwave circuit on CW Gunn oscillator performance and to describe the design of circuits capable of being tuned either mechanically or electrically over a wide frequency range.

Coherent microwave current oscillations are generated in GaAs when a dc bias voltage which exceeds the required threshold voltage ($V_T \simeq 0.32L$ V) is applied to a sample of length L (measured in microns), provided that the product of doping density and length is in the appropriate range[2], e.g., $N_0 L > 5 \times 10^{11}$ cm^{-2}. Once the device is oscillating it can be represented by an equivalent circuit consisting of a non-linear negative resistance $-R_d$ in parallel with a voltage-dependent capacitor[3] C_d as shown in Fig. 1. Capacitive susceptance appears in the external circuit because the space charge density in the device active layer, and hence the device current, cannot respond instantaneously to changes in the terminal voltage.

For reproducibility, reliability, and handling ease the GaAs chip is usually mounted in a hermatically sealed varactor type package. One such package is shown in cross-section in Fig. 2, along with its equivalent circuit. The shunt capacitor accounts for the dielectric loading caused by the ceramic and L_1 is the bonding lead inductance. The element values, measured at X-band, are $C_1 \simeq 0.2$ pf. and $L_1 \simeq 0.4$ nh. for this package.

The Gunn diode will oscillate at a frequency where the circuit impedance at the device terminals is the negative of the device impedance. The device negative resistance matches itself to the positive load resistance of the microwave circuit while the device reactance is tuned out by the circuit reactance, thus establishing the oscillation frequency. If the circuit requires a larger negative resistance than the device can supply, there will be no real power delivered to the load. The diode may oscillate in any one of a number of modes[4] depending specifically on the dc bias voltage, the device parameters $N_0 L$, the frequency f, and microwave circuit impedance.

Frequency tuning of an oscillating device can be accomplished by changing either the device impedance or the circuit impedance. The device impedance can be varied by changing the dc bias voltage. This method can be used to obtain small frequency changes such as those needed for FM or AFC[5-8]. However, large voltage changes are accompanied by variation in the device operating temperature (power dissipated), amplitude modulation, and in some instances operation of the device in an entirely different mode at a different frequency and power level. For these reasons wideband tuning is normally accomplished by tuning the circuit impedance.

MECHANICAL TUNING

Circuit tuning is most easily accomplished by mechanically changing some physical dimension of the circuit[9,10]. Fig. 3 shows a cross-section of an X-band waveguide Gunn oscillator. The Gunn diode is mounted on a cylindrical metal post centered in the broad wall of the waveguide. An iris may be used for impedance matching to the waveguide load. The frequency of the oscillator is controlled by the position of the sliding short circuit. A loss-less microwave equivalent circuit for the oscillator[11] is shown in Fig. 4. The GaAs chip is decoupled from the waveguide load Z_L by a T-section low pass filter comprising the lead inductance L1, the post inductance L_p and the parallel capacitance of the post gap and the device package. The waveguide load and the impedance of the sliding short circuit, transformed to the plane of the device, are each in series with the series capacitors, C_p, of the equivalent circuit of the post in a waveguide[12]. These impedances are in parallel with the T section filter.

The equivalent circuit parmeters have been measured with a resonance technique[13] by using dummy device packages, one open circuited, the other short circuited and by assumming a value for the lead inductance L_1=0.4 nh. The results for several different post diameters are given in Table I.

If losses in the waveguide circuit are neglected the only resistance in the circuit is the real part of Z_L. When the effective capacitance of the oscillating chip is included at the device terminals the resonant frequencies of the resulting network can be calculated. Two frequencies are found which satisfy the oscillation condition

$$\omega C_d + B_L(\omega) = 0 \qquad (1)$$

where B_L is the load susceptance at the device terminals. Only one frequency is a stable solution as may be determined by the slopes at the intersection of the $B_L(\omega)$ and $-\omega C_d$ curves plotted as a function of ω[13].

Solutions to Equation (1) for the oscillation frequency as a function of sliding short position are shown in Fig. 5 and compared with experimental results. Here the device capacitance C_d was assumed to be constant over the tuning range and to have a value of approximately $3C_0$, where $C_0 = \varepsilon A/L$ is the low field device capacitance. The quantity A is the cross-sectional area of the chip and ε is the dielectric constant of GaAs. Notice the good agreement between theory and experiment over the X-band.

While this mechanically tunable circuit is quite useful for evaluating the performance of Gunn diodes and in deducing the device characteristics it is not a practical oscillator circuit for two reasons. First, the loaded quality factor Q_L varies strongly with frequency as shown in Fig. 6. This is caused by the frequency variation of the real part of the load impedance, as viewed at the device terminals. It varies because the post acts as a transformer whose turns ratio increases with frequency. Thus the oscillator circuit is more heavily loaded at the higher frequencies. This is undesirable since in a low Q_L circuit the oscillator noise increases, frequency stability decreases, and frequency pulling due to load variation increases.

The second drawback of this circuit is that several TE[illegible] modes are allowed in the band of interest since the cavity is long, as seen in Fig. 5. This leads to multifrequency output when the oscillator is pulsed, and to mode jumping in CW operation. When the slope of the device susceptance as a function of frequency exceeds the slope of the circuit susceptance the circuit can no longer control the device oscillation frequency and the oscillation frequency jumps to a stable point in another available high Q_L mode.

In practical CW oscillators the variation in Q_L is kept small by loosely coupling the diode to a high Q circuit. In this way load variations, etc., tend to be isolated from the device. High performance tunable oscillators have been developed at X-[14,15] and K-[16] band using dielectric tuning in a fixed dimension high Q cavity.

The equivalent circuit of Fig. 4 can be used for calculation of a shunt mounted Gunn device in coaxial or rectangular waveguide-, or microstrip-cavities provided that proper estimates of L_p and $C = C_1 + C_g$ are made. For example in reduced height waveguide or microstrip, $L_p \rightarrow 0$, $C_p \rightarrow \infty$, $C = C_1$.

The equivalent circuit for series mounted devices, using the same definitions is shown in Fig. 7. The gap capacitance C_g is now the value associated with, for example, the series gap in the inner conductor of a coaxial cavity oscillator[17]. Notice that for the series mounted device, the load and tuning impedances are in series rather than in parallel as for the shunt mounted oscillator. The oscillation frequency is again given by solution to Equation 1. Wide band mechanical tuning has been obtained in coaxial circuits[9,18,19] by many workers.

ELECTRONIC TUNING

Since the oscillation frequency is controlled by the reactance of the microwave circuit, it is possible to locate electrically variable elements such as varactors or YIG or ferrite elements in the microwave circuit and vary or sweep the frequency of the oscillator.

Varactors have been successfully applied in microstrip circuits to obtain frequency variations of up to 10% at X-band[20] and 34% at S-band[21] with reasonably flat power output. The design of varactor tuned microstrip oscillators using simple equivalent circuits[22] for both varactor and oscillator has proven to be a useful approach. However, the varactor loss must be included in the design since this loss, transformed to the plane of the device has a significant effect on both the tuning range and power output of the oscillator[23]. Large tuning bandwidths (40% or greater) have not yet been obtained with varactors as a consequence of their limited capacitance variation with applied voltage. Fig. 8 shows an experimental varactor tuned X-band microstrip circuit.

Octave bandwidths and greater have been obtained by properly coupling a Gunn diode to a spherical YIG resonator[24-28]. The YIG sphere provides the frequency tunable resonant element which is coupled to the GaAs chip through the package parameters and a length of transmission line. Again the output load impedance will have a marked effect on the output power and frequency unless the chip is loosely coupled to the high Q YIG sphere. A commerical X-band swept oscillator is shown in Fig. 9 with power versus frequency shown in Fig. 10.

Other approaches using [illegible] loaded cavities[29,30] and variable phase shift elements[31] have also been demonstrated. While these tuning methods, in principle, are not capable of the wide bandwidths of the YIG tuned oscillator, they are much less critical to implement and are likely to be less expensive.

CONCLUSIONS

Since the Gunn device can be considered to be a negative resistance element its oscillation frequency is determined by the impedance of the circuit it is driving. By varying the impedance of the external circuit the oscillation frequency can be adjusted over a wide range, limited by the magnitude of the negative resistance that the oscillator can supply and the conditions for stable oscillation imposed by the circuit. This tuning range can be very large as evidenced by the results of Hanson[26] who obtained tuning from 4-12 GHz using a YIG sphere.

The power output of the Gunn oscillator depends both on the load conductance at the GaAs chip terminals and on the microwave voltage developed across that load, $P = G_L V^2/2$. Since the device dynamics are non-linear and frequency dependent, in order to obtain a flat power response it is necessary to maintain both the load conductance and susceptance reasonably constant over the desired band. This is accomplished in YIG tuned devices by loosely coupling the device to the high Q YIG resonator.

The use of high Q circuits is also desirable from the standpoint of noise, frequency stability, and isolation from load variations. However, the use of high Q circuits makes frequency modulation, pulsed operation, and injection phase-locking of these oscillators difficult. Furthermore, because the oscillators are circuit sensitive, frequency pulling over a range of operating temperatures becomes a serious problem.

The rapid improvement in Gunn oscillator performance and the extensive development efforts now going on indicate that one can look forward to widespread application of these oscillators.

ACKNOWLEDGEMENT

The author wishes to thank members of the Monsanto Microwave Products group for their continued interest. Much of the work described here

was performed at Washington University by Dr. W. C. Tsai. Particular thanks must go to Dr. M. Omori and F. Berin Fank, Varian Associates; G. King, standard Telecommunications Laboratories, Harlow, U. K.; and Drs. H. J. Pratt and M. I. Grace, Sperry Rand Research Center; and their companies for their help and for the use of their results in this presentation.

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Table I Equivalent Circuit Parameters

Post diameter (inches)	$C=C_g+C_1$ (pf.)	L_p (nh.)	C_p (pf.)
0.100	0.35	0.47	0.73
0.125	0.37	0.43	0.52
0.150	0.40	0.40	0.40
0.200	0.49	0.33	0.26
0.250	0.59	0.28	0.17

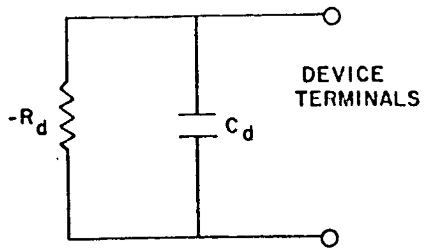

Fig. 1. Equivalent Circuit for Gunn Device.

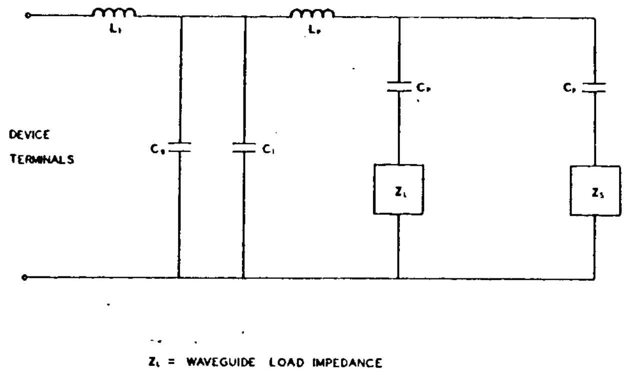

Fig. 4. Equivalent Circuit of Post Mounted Gunn Oscillator Viewed From GaAs Chip Terminals.

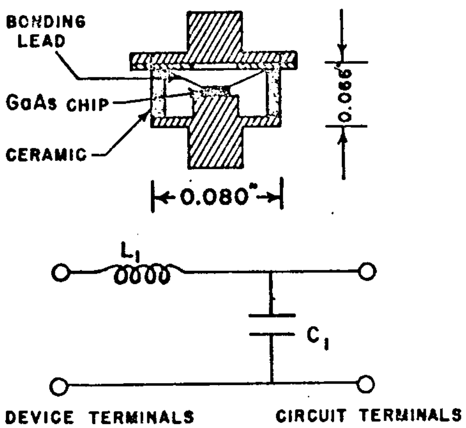

Fig. 2. Typical Packaged Gunn Diode and Its Equivalent Circuit.

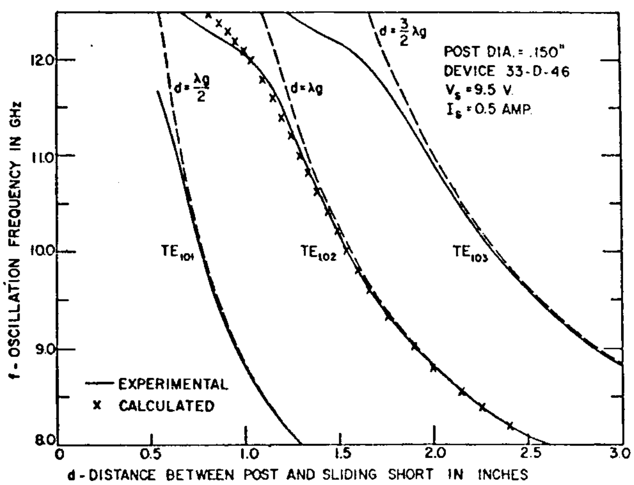

Fig. 5. Tuning Curves Showing Three Cavity Modes: Frequencies Calculated For C_d = 1.6 pf. Are Denoted by x.

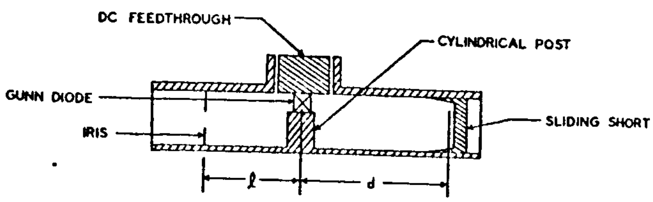

Fig. 3. Cylindrical Post Mount for Waveguide Gunn Oscillator.

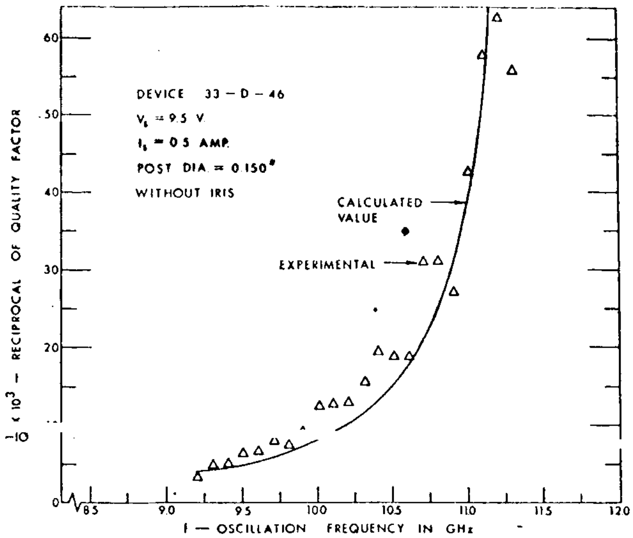

Fig. 6. Reciprocal Loaded Q Versus Oscillation Frequency

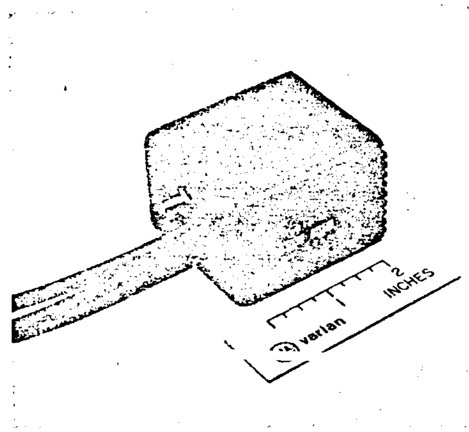

Fig. 9. X-Band YIG Tuned Gunn Oscillator. (Courtesy Varion Associates, Palo Alto, Calif.)

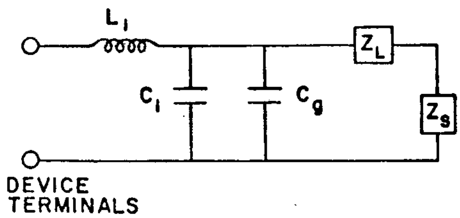

Fig. 7. Equivalent Circuit for Series Mounted Gunn Oscillator viewed From GaAs Chip Terminals.

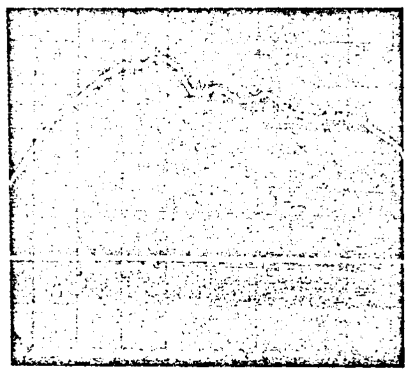

Fig. 10. Power Versus Frequency of YIG Tuned Gunn Oscillator. Frequency Markers at 8.0 and 12.4 GHz. Maximum Power: 94 mw. (Courtesy Varian Associates, Palo Alto, Calif.)

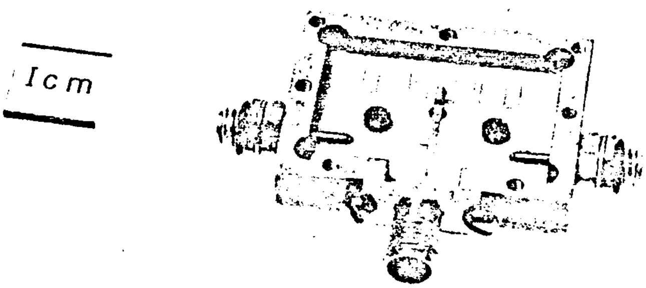

Fig. 8. X-Band Varactor Tuned Microstrip Gunn Oscillator. (Courtesy Standard Telecommunications Laboratory, Harlow, U. K.)

APPENDIX E

INTERNATIONAL DEVELOPMENT
TECHNOLOGY PROGRAM Box 1140

WASHINGTON UNIVERSITY
SAINT LOUIS, MISSOURI 63130

November 3, 1969

TO: Dr. Robert P. Morgan

FROM: Julian Scheiner

SUBJECT: Satellite Education Program - Legal Research

I. Introduction:

This memorandum contains a summary of the work that I have accomplished since I began participation on this program on October 6, 1969. It also contains suggestions for future activity in the area of legal research. My primary effort has been to survey the legal and legally related literature so as to determine which issues have occupied the legal scholars and experts within the general subject of education by communication satellite.

I have examined in excess of one hundred documents including journals, books, conference reports, and government documents. I had hoped that such a review would yield a general outline of the relevant law involved in education via communication satellite. Although my review was, of necessity, very superficial, it is my preliminary opinion that the state of the "legal art" on the subject is not sufficiently advanced to enable us to even think of it in terms of a body of law that could be summarized.

Instead, I would characterize the work that has been done in the field primarily as the raising of legal and policy issues that potentially could apply to real life situations (i.e. situations which give rise to legal conflicts between persons or states). Since the real life situations have not arisen except to a very limited extent, the rules of law necessary to deal with them are still in the early stages of formation.

II. Issues and Topics

In this section, I have attempted to list some of the more representative of these issues and topics. The treatment given them by legal writers varies widely. Some are dealt with on a highly theoretical and tentative level while a few, primarily in the area of United States domestic law, are dealt with in a detailed practical fashion.

1. Copyright law

   A. Application to Educational Television (ETV); proposals for modifications to allow partial exemption of ETV activities.

   B. Infringement of copyright by satellite relay; effect of hardware implementation on basis of infringement.

2. Tort liability for damage to property and personal injury resulting from space activities.

   A. Domestic - Federal Tort Claims Act

   B. International-United Nations General Assembly Resolution 1962 (XVIII); who bears responsibility?

3. Trusteeships (e.g. Micronesia)

   A. Political organization

   B. Self-rule

   C. Fiduciary reposnsibility of Trustee

4. Liability for program content

   A. Propaganda (warmongering)

   B. Right of privacy

   C. Libel

   D. Freedom of expression as a right in international and domestic law

5. Sources of International Public law

   A. United Nations Charter (Soverign equality of states)

   B. United Nations General Assembly resolutions

   C. International treaties and conventions

      1. International Telecommunications Union (ITU) Convention & Regulations

      2. INTELSAT

      3. 1967 Treaty on Exploration of Space

      4. International Bureaux for the Protection of Intellectual Property (BIRPI)

6. State Sovereignty

   A. Innocent passage concept borrowed from law of sea

   B. 1967 Treaty on Exploration of Space: the no-sovereignty provision

7. Exclusivity of ETV programming materials by private contract on the part of NET in light of:

   A. FCC rules

   B. Public Broadcasting law

   C. Public support by
      1) tax funds
      2) tax-exempt contributions

   D. All Channel Receiver Law

8. Exculusivity of spectrum allocation

   A. FCC licensing practice

      1. Terrestrial (CATV)
      2. Electromagnetic

   B. COMSAT

   C. Relationship and division of authority between FCC, COMSAT, INTELSAT and NASA

   D. Regulation, monopoly, and antitrust

   E. Creating property rights in the electromagnetic spectrum

9. Control of entry into a state of external transmissions

   A. State jurisdiction over private broadcasters located in international waters

   B. Legitimacy of state jamming

10. Soviet law

11. Nationality of Spacecraft

   A. State registration-privileges and immunities by analogy to maritime law

   B. Licensing of private entrepreneurs

III. Comments

From an analysis of the listing given above, I believe that it would not be a practical goal to attempt to provide a survey of the relevant law on the subject because

1. The number and scope of potential issues and topics is too great, and the relationship between one and another is too remote to allow for complete coverage.

2. The rules of law are not sufficiently developed to allow for reasonably definitive conclusions.

There are two other alternative approaches:

1. Starting with a reasonably concrete proposal including the country or region to be investigated, the national and international agencies, the type of Vehicle and transmission, and the program content involved, it would be possible to begin the task of defining the problems that probably would arise and to suggest alternative solutions.

2. The list of issues and topics above could be assigned priorities and each could be accordingly researched in some degree of depth. In this connection, it should be noted that the list of topics and issues given is not exhaustive. There are a number of documents that I am aware of but have not yet examined. I am confident that the list could and should be expanded.

I would be happy to entertain other novel approaches to the problem and I solicit your opinions on the subject.

In addition to the approaches discussed immediately above, there is one effort that I strongly feel would be useful to the program - the preparation of an annotated bibliography of legal materials. This would yield two benefits:

1. It would allow non-legal participants in the program to gain some insight into the legal aspects involved and

2. It would allow future legal researchers on the program to avoid the chore of wading through irrelevant, repetitive, and out dated materials (of which there are many!).

APPENDIX F

Some Comments on Multidisciplinary Studies and the University

by R. P. Morgan

A recent paper by H. B. Quinn* has highlighted the opportunities and pitfalls associated with multidisciplinary university research. Because the current Washington U.-NASA program on Application of Satellite Communication to Educational Development is such a program, and because it represents an experiment in a new type of university venture, I would like to take this opportunity to comment on some of the advantages and difficulties encountered at a relatively early stage of program development.

First, it is important to define what the general program objectives are. We are trying to carry out a program which cuts across a broad range of academic or departmental lines to involve a large number of disciplines. We are not talking about a coupling of two areas, like engineering and medicine (bioengineering) or a program which supports materials research by funding individuals in physics, chemistry and mechanical engineering to "do their own thing". Furthermore, the many disciplines are not brought into the program on their own terms but more so in terms of what they can contribute to the overall program effort. The latter, therefore, has a unifying theme, which in this case is the application and impact of a specific technological innovation, i.e. a synchronous communications satellite, on the improvement of education.

What then, are the ingredients which go into a successful program? Even more fundamental than that, how does one <u>define</u> a successful program? I want to try to answer these questions in the context of the specific program which I am coordinating.

One element surely has to be the participation of a significant number of faculty members and students from a variety of traditional fields. To achieve this participation requires that a small group of individuals be genuinely interested in the program area, no matter how imprecisely defined, at the outset. These individuals (a critical mass might be two or three or four) have to be willing to do the necessary spadework and planning and

*Quinn, H. B., "Multidisciplinary studies and the Universities".

and make certain commitments. The involvement of others can come about by a variety of means. In our specific case, instances arose in which students were attracted to the program prior to the involvement of faculty members from their departments.

The presence on campus of one individual with no real departmental ties but with academic qualifications and a commitment to certain kinds of multidisciplinary program endeavors is a key factor in program development. Such an individual can get students and faculty members thinking about new ideas, new problem areas, and even new funding sources. Oftimes, the initial contact comes through participation in an interdisciplinary course, like the IDTS (International Development Technology) sequence which exists at Washington University.

Perhaps the most significant criterion for evaluating a program of the type under consideration is the kind of experience which the student participant receives. This might range from a one term exposure in a three-credit course or a summer's research experience, to a PhD thesis. Consider the latter for a moment. A conventional PhD experience in, say, electrical engineering consists of a sequence of course work, usually <u>all</u> technical, plus a highly specialized technical investigation. It seems to me that the experience of a PhD candidate involved in a multidisciplinary research project might differ from this in at least two ways.

1. His experience might be similar to the conventional experience but somewhat broader. As a minimum, he should be required to participate in an interdisciplinary seminar course with people of other disciplines which focuses on the overall program area. He might be encouraged to take one or two other courses which broaden his experience instead of all technical courses. Finally, his thesis, while predominantly that of a technical electrical engineer, might reflect an awareness not only of the conventional historical background of his specific technical work, but the larger context of what his work means as far as society as a whole is concerned.

2. In this case, the subject matter for the thesis is relevant to overall systems or program considerations and fits less neatly into departments or schools. For example, innovative thinking

which leads to new concepts for satellite utilization and examines its impact on the U. S. educational system might be difficult to justify in many universities. This kind of "glue" is needed to hold the more disciplinarian aspects of the program together.

We expect both of these kinds of situations to arise in this program. They already have. The first will be easier to deal with than the second. Both should have a place in our thinking at this stage of development of multidisciplinary research programs.

Another key element of this program is that we are looking at a field of technology which can have broad social impact. There have been two tendencies in our society which a program of this type can help correct. On one hand, technological development is taking place at a fantastic rate, with much less thought going into what the real implications of such development are than to how to sell or push such development. On the other extreme, are those who choose to "turn off" technology altogether. One function of this program will be to bring technologists and non-technologists together to carefully examine the social impact of a specific technological innovation and provide a framework for dialogue between opposing points of view.

However, I want to make it clear that I see this as more than a program which examines the impact of technology on society. My view is more action-oriented than evaluation-oriented. It starts from the premise that there are needs, serious ones, in terms of educating people the world over. Technology in general, and communications satellites in particular have a role to play in meeting those needs. To determine what that role is will require top-flight minds. We need more than broad, once over lightly, systems engineering studies on one hand, and highly technical, disconnected, unrelated studies on the other.

Whereas we are not over the hump yet, I think we are well on our way to doing some new kinds of things within a university framework.

APPENDIX G

INTERNATIONAL DEVELOPMENT
TECHNOLOGY PROGRAM
Box 1140

WASHINGTON UNIVERSITY
SAINT LOUIS, MISSOURI 63130

India Trip Report, R. P. Morgan, Nov. 10-26, 1969

During the period from November 10 to 26, 1969, I had the opportunity to travel to India. I made the trip in my capacity as Director of Washington University's International Development Technology Center. Among the purposes of the trip were:

1. To attend the World Conference of the Society for International Development, (S.I.D.) held in New Delhi, Nov. 14-17, 1969. I traveled from the United States to India and returned via the S.I.D. Charter flight which had been arranged for the conference.
2. To experience India for the first time and to explore the possibilities for cooperative programs between Washington University's International Development Technology Center and Indian institutions, primarily in two areas of interest; a) Application of Satellite Communications to Educational Development, and b) Development of Indigenous Materials for Low-Cost Housing and other applications. Programs in both of these areas have been initiated at Washington University (see enclosed article). This latter part of my trip, from the period of November 18-25, 1969, was supported by an Invitational Travel Grant from the National Science Foundation's Cooperative Science Program in India, funds for which are provided by the Agency for International Development (USAID).

There were a number of events at the S.I.D. meeting which were relevant to the satellite applications program, including a panel discussion entitled "Is a Breakthrough Possible Through Intensive Use of TV?" which featured such panelists as Lyle Nelson, (Stanford), B. Prasada (I.I.T. Kanpur) and John Willings (UNESCO). Dr. Vikram Sarabhai, Chairman of the Indian Atomic Energy Commission was a featured banquet speaker on the subject, "Television for Development", in which he described the DAE-NASA Satellite ITV Experiment.

While in New Delhi, I had the opportunity to have a private luncheon with Dr. Sarabhai. In addition I was a guest at a luncheon sponsored by the Department of Atomic Energy which was attended by Lyle Nelson (Stanford), Daniel Lerner (M.I.T.), Harold Howe (Ford Foundation) and representatives of various Indian organizations who have been meeting on a monthly basis to work out the details of the Satellite experiment. Included were representatives of the Indian Space Research Organization, All-India Radio, the New Delhi Television Center, Ministry of Education, etc. In addition, I spent the better part of one day with Mr. Chaman Lal of the Indian Space Research Organization, visited an Indian village where a television program was in progress, and had discussions with Harold Howe and Peter Geithner of the Ford Foundation, Max Hellman and Edward Mikol of the National Science Foundation, G. S. Hammond and Irwin Slesnick of USAID Education Division, David Rogers of the Peace Corps, Ward Morehouse (S.U.N.Y.), Morris Asimov (U.C.L.A.), B. S. Rao and V. K. Chitnis of the Indian Space Research Organization, and B. Prasada (I.I.T.Kanpur).

I spent 36 hours in Ahmedabad visiting with Dr. V. K. Chitnis of the Physical Research Laboratory. Dr. Chitnis has a leading role in the Satellite ITV experiment. I had the opportunity to tour the Experimental Satellite Earth Station in Ahmedabad, and to visit both the Community Science Centre and the National Design Institute.

I then traveled to Kanpur where I spent two days at the Indian Institute of Technology. I held lengthy discussions with Dr. B. Prasada, Chairman of the Department of Electrical Engineering and in charge of a student operated closed circuit Television Centre, and with Gilbert Oakley, who is in charge of the Indo-American Program at I.I.T. Kanpur. Meetings were also held with Dr. E. C. Subbarao, Dean of Faculties and Dr. J. K. Sridhar Rao of the Department of Civil Engineering to discuss mutual interests in the fields of applied materials research and development.

A final in-country trip was taken to Roorkee where discussions were held with G. S. Ramaswamy, Director of the Structural Engineering Research Centre and S.M.K. Chetty of the Central Building Research Institute.

Although two weeks is hardly sufficient time for arriving at any conclusions or recommendations, a few general remarks may be in order.

1. <u>The DAE-NASA Satellite ITV Experiment.</u>

   This experiment would appear to be a significant undertaking which is relevant to the developmental needs of India. In the brief time I was in India, I had the opportunity to have discussions with many of the key people associated with the Satellite ITV program. From the point of view of Washington University's International Development Technology Center, we are interested in exploring further the possibilities for cooperative research and development efforts initially in the areas of ground-based hardware (low-cost receiver/front end/power source) and, at an intermediate stage, in the software aspects. We believe that interaction between the Indian program and our own university activity in the satellite application area will be mutually beneficial.

2. <u>Indian Institutions.</u>

   I was most favorably impressed by those institutions which I visited. The Indian Institute of Technology at Kanpur is a vibrant institution with quality faculty and quality students. I hope that they will have the opportunity to participate in the Satellite ITV experiment, both in the hardware and software aspects. In particular, the fact that Kanpur is one of the chosen pilot areas for direct broadcast reception, coupled with the campus Television Centre and the nearby "Literacy Village" in Lucknow, appears to be a particularly good combination. A student project, "Project ACME", which focuses on overall systems and on hardware aspects of satellite-education, has already been carried out at IIT Kanpur.

The Structural Engineering Research Centre (SCRC) and the Central Building Research Institute (CBRI) appear to be well-developed, applied institutions which are responding well to the developmental needs of the country. The CBRI is doing work on fiber reinforcement using natural fibers which is related to our own efforts at Washington University.

Although the needs of the country remain great, it was my privilege to talk to many excellent scientists and engineers at first-rate institutions. It seems to me that more emphasis should be put in the future on cooperative university programs which provide good communications between Indian and U. S. Institutions pursuing programs of mutual interest. Such programs could provide Indian students studying in U. S. Universities with experiences which are relevant to their country and, furthermore, with contacts back home which could eventually result in meaningful employment in India. Such programs could result in a transfer of appropriate technology without heavy U. S. involvement overseas.

In conclusion, I wish to thank the National Science Foundation and U. S. AID for the Invitational Travel support which I received. Members of the Foundation staff in New Delhi were most helpful in arranging for the necessary visits and paperwork. In fact, almost without exception, all of the people whom I dealt with, be they Indian or American, were most helpful and cordial. My brief visit was optimal from the point of view of seeing many of the people I wanted to see in a relatively short time.

It is my hope that as a result of my visit, opportunities will arise for cooperative efforts between our International Development Technology Center and interested parties in India which will be of mutual benefit to both our countries.

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APPENDIX H

an international development technology center

Robert P. Morgan

The International Development Technology Center at Washington University was initiated July 1, 1968. Its main focus is the application of science and technology to the solution of problems faced by people in the less-developed areas of the world. Teaching, research, and service activities emphasize creative efforts to help less affluent nations utilize science and technology for the benefit of their people.

The orientation of the center represents a departure from previous United States university involvement in world affairs. Emphasis is placed not only upon the generation of new and useful technological processes, devices, and knowledge but also upon the coupling of technology to local socioeconomic environments so as to have a substantive impact for constructive international development. Key operational objectives of the center are that it be truly interdisciplinary, involving many diverse segments of the Washington University community, and that it have close cooperative ties with counterpart institutions in developing countries. The relatively small size of Washington University and its broad spectrum of disciplines are well suited for the interdisciplinary activity required to achieve the primary goal of the center—to contribute to a better way of life for people in less-developed areas through the enlightened use of science and technology.

Program Objectives

Three elements relating to the program of the center are of particular relevance to the goals and objectives of Washington University.

1. The center brings to the university a new set of challenging problems which, in many instances, can only be solved by efforts which are at the frontiers of scholarship in a broad spectrum of professional disciplines.

2. The center represents an effort to bridge the gap between the "two cultures" by fostering interaction among faculty members and students with a wide variety of academic backgrounds.

3. The center, with its emphasis on attempting to narrow the widening gap in living standards between the rich and the poor, directs itself to real and relevant problems of concern to many faculty members and students.

Mr. Morgan is director of the International Development Technology Center at Washington University, St. Louis, Missouri. This article is adapted from a paper presented at the ASEE Annual Meeting and Conferences at The Pennsylvania State University in June 1969.

On July 1, 1968, a director was appointed, and a commitment was made to support a program from in-house university funds for a minimum of two years. The director of the center currently reports to the dean of the School of Engineering and Applied Science.

Research and Development Activity

An important goal of the center is the establishment of cooperative research and development programs with counterpart institutions in developing countries. The orientation of these programs revolves around needs rather than conventional physical or academic disciplines. The approach is to list problem areas of prime importance such as food, shelter, and education and then try to identify resources at Washington University which can contribute to their solution. Two fields of activity are now underway.

1. *Composite Materials, Housing, and Economic Development.* A major component of the research activity in the School of Engineering and Applied Science is the Materials Research Laboratory and the graduate program in Materials Science and Engineering. The laboratory has pioneered in the field of high-performance composite materials with high strength-to-weight ratios for aerospace and other commercial product applications. Much of the research and technology associated with this effort has potential for application to relatively inexpensive materials which might be of importance in international development. For example, reinforcement of soil-cements or concretes with indigenous organic fibers might produce structural elements to help meet the need for low-cost housing in developing areas. Other products might be created which could serve to strengthen the economic base of less-developed sectors.

Discussions between Washington University faculty members in materials science and engineering, civil engineering, architecture, business, economics and sociology led to the preparation of a preliminary proposal for a cooperative international program on the development and utilization of indigenous materials for low-cost housing in developing countries. In this connection a trip was undertaken to four countries in Latin America in April 1969 by the directors of the Materials Research Laboratory and the International Development Technology Center to explore the possibilities for cooperative research and development programs with suitable counterpart institutions. Some preliminary experiments are being carried out at Washington University, while links between institutions are being established.

2. *Satellite Communications and Mass Education.* The International Development Technology Center has initiated research on the use of communication satellites for mass education in developing countries. Three research assistants were active on the project during summer 1968: an electrical engineering graduate student from Africa and two men returned from the Peace Corps, one an economics student and the other a Latin American studies major. Advising the students were interested professors from physics, electrical engineering, economics, and education. This interdisciplinary research effort is being greatly expanded as a result of a recent grant from NASA. Both domestic and international applications of satellite communications to educational development are being investigated. Emphasis is on ground-based hardware, utilizing new developments in solid-state microwave devices, educational software, and legal, economic, social, and political factors.

A pattern begins to emerge from these projects. First, the International Development Technology Center catalyzes interest and resources at Washington University around problem areas of importance in international development, e.g., housing and education. The projects which are most compatible with the interests of faculty members in engineering and applied science are those in which the latest scientific and technological research is redirected or adapted towards meeting needs in developing countries. Around this technological nucleus is an interdisciplinary matrix of faculty members and students capable of looking at all aspects of the problem areas under study. Finally, a close link with an institution in the area of potential application is required to insure that the effort will have impact, be truly relevant to needs, and result in both a transfer of technology and a strengthening of human resources.

The Educational Base

Two new studies programs are being offered in the School of Engineering and Applied Science: an International Development Studies program for undergraduates and an International Development Technology Studies program for master's level candidates. In both cases, no new degrees are offered. Instead, activity related to international development is injected into existing degree offerings.

1. *International Development Studies (Undergraduate).* At the undergraduate level, the International Development Studies program consists of relevant courses from outside the School of Engineering and Applied Science, as well as interdisciplinary seminars developed with the active participation of engineering faculty members. These courses may be applied towards satisfying the common studies requirements of the School for Humanities and Social Science electives. Students who complete an approved sequence of courses totaling at least 12 units will receive a certificate stating that they have completed the international development studies program of the School of Engineering and Applied Science at Washington University. One of the two interdisciplinary seminars must be included. Other courses may be chosen from the following, some of which have prerequisites in economics or sociology:

The Third World—Myth and Reality
U. S. Foreign Policy Toward Developing Nations
Far Eastern Politics
International Politics
Latin American Politics
African Politics
Economic Development
Economic Trends in the Far East
International Economics
Economic Development of Latin America
Economic Development of the Far East
People and Cultures of the World
Mexico: People and Institutions
Brazil: People and Institutions
Contemporary India: Social Change and Development
Social Development in Latin America
Transfer of Technology to Developing Countries

2. *International Development Technology Studies (Graduate).* At the graduate level, opportunities for coordinated study in international development technology are available to students who are M. S. candidates in the degree-granting departments and programs of the School of Engineering and Applied Science. Although no formal degree in this field is offered, several departments permit up to 12 credit hours in international development technology studies to be applied towards the requirements for the M.S.

Studies in international development technology are particularly recommended for United States students with a strong interest in world affairs and for foreign students interested in the role of technology in the development of their own countries. The transcripts of students successfully completing the requirements in international development technology will be appropriately designated.

Requirements

The International Development Technology Studies program requires a thesis, project, or fieldwork experience equivalent to six hours of graduate credit and related to the application of technology to problems in international development. The thesis, project, or fieldwork experience must be approved by the director of the center. Projects may be undertaken either here or at cooperating institutions. Under certain conditions, relevant Peace Corps experience may be used to satisfy this requirement. It also requires 12 credit hours chosen from the International Development Technology Seminar, Special Topics in International Development Technology, Transfer of Technology to Developing Countries, independent work (international development technology), and one course relevant to international development offered outside the School of Engineering and Applied Science, if approved by the director of the center. Up to six credit hours towards meeting this requirement will be waived for students who have taken courses on this list while undergraduates at Washington University, or for equivalent courses taken elsewhere.

In general, the requirements provide a flexible framework in which to create a program which best suits the student's interest. Students completing the requirements will possess an awareness of international development needs and the role of their profession in meeting those needs. They will have had some practice in applying themselves to the solution of real problems. In addition, they will be made aware of the interaction between technology and the broader set of cultural, economic and business factors which oftimes limit technological innovation.

Areas of Interest

Areas of current interest to Washington University faculty members which might form the basis for thesis or project work include application of composite materials technology to the development and utilization of indigenous materials for low-cost housing; application of space science and technology to mass education in developing countries; power sources for developing countries; application of computers to economic and industrial development; and studies in transfer of technology to developing countries. Every effort is made to accommodate other individual interests.

International development technology studies should be of particular interest to engineering and applied science students who wish to participate in the Peace Corps. Under certain conditions, engineers with bachelor's degrees may earn up to 12 credit hours towards satisfying the international development technology requirements based upon suitable Peace Corps experiences. Credit may be granted for project, thesis, or fieldwork experiences which have the approval of the center prior to being carried out overseas and which will be completed upon return to Washington University, as well as for suitable independent work experiences.

Interdisciplinary Seminars

In each of the above studies programs, a key element is the interdisciplinary seminar. In 1968-69, three such seminars were held. In the fall semester, the international development technology seminar provided an overview of the role of science and technology in international development. Guest speakers from government, industry, and many university disciplines took part. The seminar was attended by 11 seniors and graduate students in engineering, physics, social work, education, and architecture from six different countries. A relevant term paper was required. Texts included, among others, *Science and Economic Development*, by R. L. Meier, and *Man's Struggle for Shelter in an Urbanizing World*, by Charles Abrams.

In the spring a more specialized seminar of a special topics nature emphasized low-cost housing and construction. Eight graduate students were in attendance from engineering, architecture, and social work. The course looked at low-cost housing from an interdisciplinary point of view (economics, materials, building methods, sociology, needs, etc.) The course augmented the materials research effort described above.

Also during the spring semester, the course on Science, Technology and International Development was attended by 25 undergraduates, representing majors in engineering, architecture, business, history, psychology, and Latin American studies. Some required textbooks were *The Two Cultures*, by C. P. Snow, *The President's Science Advisory Committee Report on the World Food Problem*, and *The World Educational Crisis*, by Phillip Coombs.

The feedback from students has been good. Although the courses have a science and technology focus, they attract students from outside engineering as well as engineers. In at least two instances, students who attended these seminars are now deeply involved in relevant research projects.

These seminar courses must be kept flexible. In the 1969-70 International Development Technology seminar, with an enrollment of 20 graduate students, education is being emphasized instead of housing. In a new course dealing with technology and poverty in the United States, attended by 25 undergraduates, hazards and benefits which can result from technology are discussed.

A View Toward The Future H3

The International Development Technology Center in the future should encompass the major functions described below.

Research and Development. Research institutes, universities, and other organizations in developing countries are working to increase industrial and agricultural productivity by means of technological innovation. The center will help such organizations to generate or adapt the necessary technology and, equally important, to couple the technology to the local economy and culture. Engineers, architects, business administrators, and social and natural scientists at the center will work closely with their counterparts in cooperating institutions overseas. In addition to solving immediate problems, the center will carry out research on the processes of technological innovation and the transfer of technology to developing countries.

Education. The center will aid in preparing both American and foreign students for careers in international development. Courses at undergraduate and graduate levels present technological and socioeconomic aspects of development in an integrated manner. A new master's minor program option in international development technology has been established in the School of Engineering and Applied Science, requiring completion of a thesis or project based upon work at the center. It is anticipated that other professional schools at Washington University will develop program options which interact with the center.

Demonstration and Training. Center activities falling within this category will include demonstration to foreign nationals of technology with potential for adaptation to local needs, using working models of devices and pilot-plant production facilities; training programs for Peace Corps volunteers; special seminars for government, foundation, and industrial personnel; and training of technicians for developing countries, with emphasis on research to develop the necessary methodology and materials.

Much of this activity will be carried out at Washington University's 2,000-acre Tyson Valley Research Park, located 15 miles southwest of the main campus.

Publications and Information. A wide variety of reports, handbooks, and monographs are planned. The center hopes to publish a journal of development technology to provide an outlet for the work of researchers in this field.

Immediate plans call for a strengthening of the research and educational programs already underway. In addition, two other directions are likely in the near future. The first involves the creation of a program in small business development, with strong engineering and business school inputs. The second involves the application of technology to problems of poverty in the United States. An undergraduate seminar is being held this fall to define objectives and opportunities, with students from a variety of disciplines participating.

With adequate implementation and support, the center can be a significant part of an effort to relate science and technology more directly to the needs of poor people in the less-developed areas of the world as well as to those in need in our own society. It is becoming increasingly clear that such an effort must be made if both the engineering profession and society itself are to survive and fulfill their noblest aspirations. △

APPENDIX I

INTERNATIONAL DEVELOPMENT
TECHNOLOGY PROGRAM Box 1140

WASHINGTON UNIVERSITY
SAINT LOUIS, MISSOURI 63130

August 13, 1969

Mr. Herbert B. Quinn, Chief
Research Branch
Office of University Affairs
National Aeronautics and Space
Administration
Washington, D. C. 20546

Dear Mr. Quinn:

Thank you very much for your letter of July 22, 1969 informing me that you have asked approval of a $200,000 procurement request to fund Washington University's proposal on "Application of Satellite Communication to Educational Development." We are most appreciative of this indication of interest and support.

In this letter, I shall respond to your request for a succinct statement of objectives against which progress can be measured at the conclusion of Phase I, a period of not more than six months from receipt of contract, operating on a budget of $25,000. Our objectives during Phase I are as follows:

1. To review, in a comprehensive manner, both past and present efforts which pertain to the use of satellite communication in educational development. Included in this review will be relevant material from the fields of engineering, economics, education, communications, law, political science and sociology. Literature relating to both domestic and international application of satellite communication will be examined. We will survey a wide variety of organizations currently active in the field of interest, including educational associations and broadcasting organizations. Visits to installations such as NASA's Lewis Research Center and General Electric Space Systems Center at Valley Forge will be undertaken to insure that the program will interact effectively with the work of NASA and its contractors.

2. To firmly establish a suitable management and operating structure for bringing together all the skills required to attack the satellite utilization problem in a truly interdisciplinary manner. At a minimum, by the end of Phase I, active participation of faculty members and students in engineering, education, economics and at least one field related to public policy (political science, sociology,

law) will be required. Our pilot experience this summer, with students and faculty members from three of these disciplines, leads us to believe that this objective can be readily achieved. The organizational structure proposed for the execution of Phase II is depicted on the following page.

3. To identify two sub-programs requiring detailed interdisciplinary analyses and experiments during Phase II. The general criteria for these sub-programs are as follows:

   a. One sub-program will focus upon bringing about improvement in education in the United States or its trust territories. In terms of man-hours of effort, this domestic activity will constitute a minimum of 50% of the total program effort.

   b. One sub-program will be directed towards the application of satellite technology to meeting educational needs in one or more of the less developed nations of the world.

   c. Both sub-programs will deal with geopolitical regions which show promise of moving beyond the planning stage and into the pilot project stage for educational satellite utilization during the early 1970's.

4. To bring Phase II of the program into sharp focus. This latter phase will culminate in analyses and/or experiments which will contribute new knowledge concerning satellite use for education. In general, the program will seek to devise practical strategies for utilizing satellite communication to meet educational needs which take into account economic and public policy factors.

During Phase I, because of our special competence in the field of microwave integrated circuits and solid-state, microwave oscillators, we will give careful attention to the contributions which these technologies can make to reducing costs, within the context of overall systems analysis.

During Phase I, we will develop the interdisciplinary capability to do research in the following areas:

a. Economic analysis of alternative systems for electronic distribution of educational media.

b. Socio-political factors in utilization of satellite communication for education.

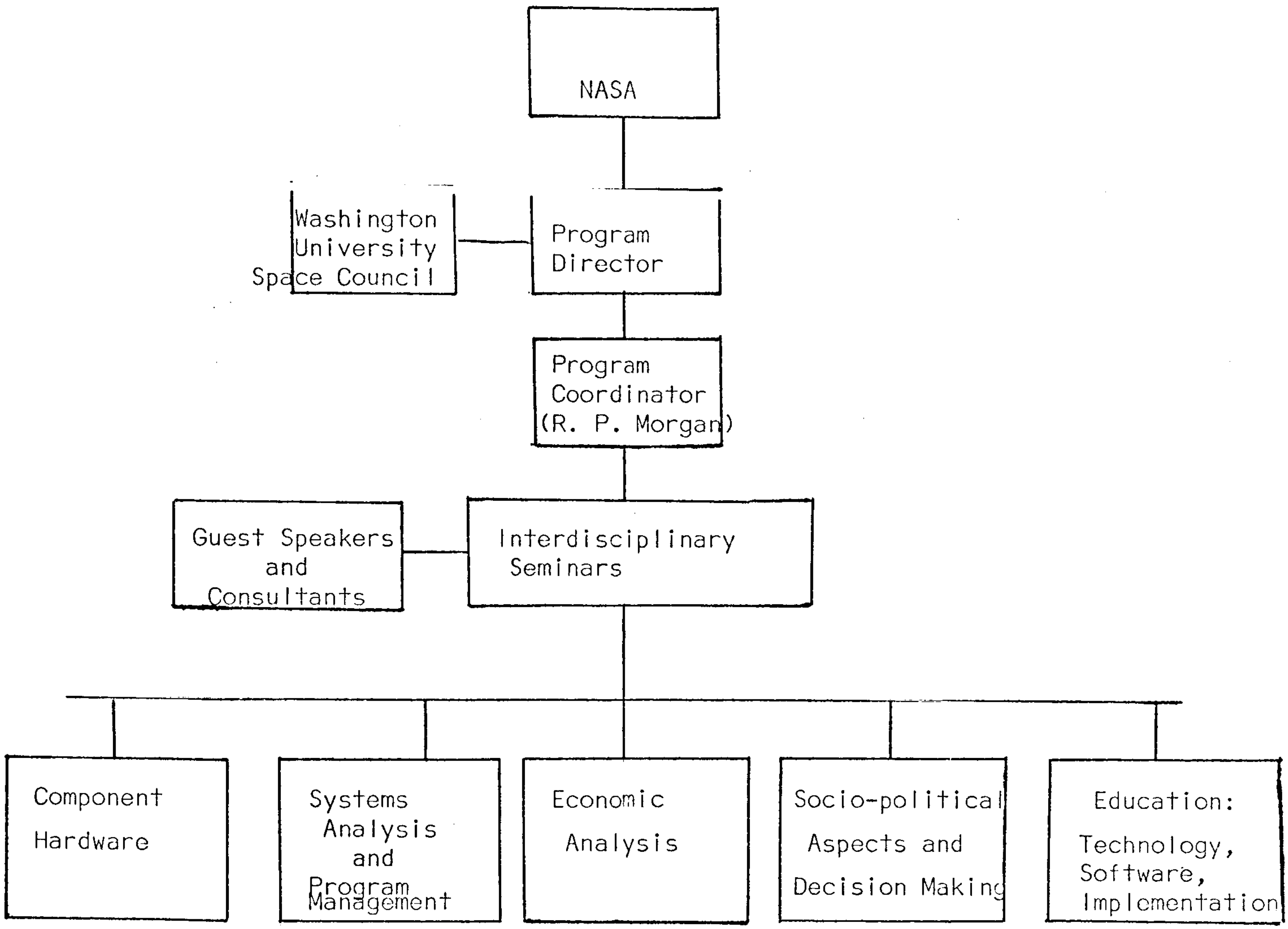
c. Educational technology and software; effectiveness and strategies for implementation.

ORGANIZATIONAL STRUCTURE

Washington University Program

on

Application of Satellite Communication to Educational Development



Research Assistants: Summer, 1969

A. Sene, Electrical Engineering
J. DuMolin, Education
R. Woodward, Economics

Emphasis will be placed in all phases of the program upon heavy involvement of faculty members and students within an interdisciplinary context. As the recent President's Task Force Report on Communications Policy has pointed out, there is significant need for "advanced interdisciplinary training of communications experts--economists, lawyers, engineers, management experts, social scientists and others . . . to deal with problems of communications policy which transcend the confines of any single discipline." We deem this statement to define one of our major overall program objectives. To achieve this objective, a variety of strategies will be employed, including the following:

a. The International Development Technology Seminar (a three credit, graduate level course) will be held during Phase I. This interdisciplinary course, attended by students from a variety of professional disciplines, will focus upon the role of science and technology in meeting educational needs in the less-developed nations as well as the less-developed areas of the United States. Guest speakers from industry and government will participate.

b. The Project Coordinator will meet at least every two weeks with faculty members and graduate students representing the spectrum of activities depicted on page 3. These meetings will permit a detailed exchange of views among principal participants in the program.

We also deem it of particular importance that Washington University's effort be closely coupled to the particular area of application of the program. This coupling will be accomplished by establishing working relationships with counterpart educational institutions or other organizations in the regions of interest. In some cases, it may be desirable for Washington University students and faculty members to carry out a portion of their research efforts off campus. Conversely, personnel from counterpart organizations might be effectively utilized by providing for periods of residence at Washington University.

Finally, we believe that the program is extremely relevant to the work of NASA for the following reasons:

a. It emphasizes the application of space science and technology to help solve the educational crisis facing our nation and the world.

b. It will train future professionals in a variety of disciplines who can fill a vital need in both the public and private sector for individuals who are knowledgeable about broad areas of application of the national aeronautics and space program.

I hope that the information provided above will be satisfactory. If further information is required, please do not hesitate to call upon me.

Yours sincerely,

Robert P. Morgan

Robert P. Morgan
Director

RPM:pon

APPENDIX J

Biographies of Faculty Members and Professional Personnel

Currently Active in Program

R. P. Morgan, Program Coordinator

F. J. Rosenbaum, Electrical Engineering

D. L. Snyder, Electrical Engineering

E. Greenberg, Economics

N. Bernstein, Law

B. Anderson, Education

R. M. Walker, Physics

H. M. Ohlman, Research Applied Scientist

ROBERT P. MORGAN
Director, International Development Technology Center
Associate Professor of Engineering
Washington University

Nationality: U. S. Citizen. Born February 26, 1934, Brooklyn, New York.

Education:

B.Ch.E.	Chemical Engineering, The Cooper Union, 1956
M.S.	Nuclear Engineering, Massachusetts Institute of Technology, 1959
Nucl. E.	Massachusetts Institute of Technology, 1961
PhD	Chemical Engineering, Rensselaer Polytechnic Institute, 1965

Professional Experience:

1956,1958 (Summers)	Engineer, Atomics International, Canoga Park, California
1959-1960	Instructor (Full-Time) and Assistant Director, Massachusetts Institute of Technology School of Engineering Practice at Oak Ridge, Tennessee
1960-1964	Instructor, (Full-Time) Department of Chemical Engineering, Rennsselaer Polytechnic Institute, Troy, New York
1964-1968	Assistant Professor, Nuclear and Chemical Engineering, University of Missouri, Columbia, Missouri
1966-1967	Chairman, Nuclear Engineering Program, University of Missouri, Columbia, Missouri
1965 (Summer)	Resident Research Associate, Reactor Engineering Division, Argonne National Laboratory, Argonne, Illinois
1966 (Summer)	College Professor, Spert Analysis Group, Atomic Energy Division, Phillips Petroleum Company, Idaho Falls, Idaho
1967 (Summer)	Consultant, International Development Technology Program, Washington University, St. Louis, Missouri
1968-1969	Associate Professor (with Tenure), Nuclear and Chemical Engineering, University of Missouri, Columbia (on leave of absence as Acting Director, International Development Technology Center, Washington University, St. Louis, Missouri)
1968-1969	Visiting Associate Professor of Engineering, Acting Director of International Development Technology Center, Washington University, St. Louis, Missouri.
1969 -	Associate Professor of Engineering, Director of International Development Technology Center, Washington University, St. Louis, Missouri.

Professional Activities:

Co-Chairman, Session on "Systems for Emerging Nations", 3rd American Institute of Aeronautics and Astronautics Conference on Satellite Communications Systems, to be held in Los Angeles, April 6-8, 1970.

Consultant (Invitational Travel) to National Science Foundation's Cooperative Science Program, New Delhi, India, Nov. 18-25, 1969.

Program Coordinator, Washington University - NASA Program on Application of Satellite Communication to Educational Development, Sept. 1, 1969 -.

Corporate Member, Volunteers for International Technical Assistance (VITA) and Founder of Columbia, Missouri VITA Chapter. Represented VITA at F. A. O. Seminar, Des Moines, Iowa, April 1967. VITA is a volunteer organization of over 5,000 scientists and engineers who work on practical problems of technical development faced by people in developing countries.

Member, International Engineering Education Committee of the American Society for Engineering Education. Appointed Program Chairman for Committee Sessions at the A.S.E.E. Annual Meeting held in June 1969. Chairman, International Program Committee, Northeast New York Section, American Institute of Chemical Engineers, 1961-63.

Presented invited paper on "International Directions in U.S. Engineering Education" at Conference on "Engineering in International Development," Estes Park, Colorado, August 1967. Spoke on "Engineering for Developing Nations" at Argonne National Laboratory, Chicago, August 1967.

Spoke on "Engineering Education for International Development" at Engineering Foundation Research Conference on "Industrialization in Developing Nations," "Milwaukee, Wisconsin, August 1969. Presented paper on "The International Development Technology Center of Washington University" at Annual Meeting, American Society for Engineering Education, College Park, Pennsylvania June,1969.

Recent meetings attended include "International Conference on Interdisciplinary Aspects of Engineering Technology for Developing Countries," Pittsburgh, Pennsylvania, October 1968; "Conference on Impact of Technology and Modernization on Latin American Society," St. Louis Missouri, January 1968; "Conference on Rural Development in the United States," St. Louis, Missouri, August 1969.

Member, Subcommittee on International Programs of Faculty Policy Committee, University of Missouri, Columbia, 1967-1968; Chairman, International Program Committee, School of Engineering, University of Missouri, Columbia, 1967-1968. Prepared proposal for International Development Technology Center, Washington University, Summer 1967. Currently teaching International Development Technology Courses at Washington University, St. Louis, Missouri.

Invited to serve on Educational Program Committee for the Second Inter-American Materials Conference to be held in Mexico City, August 1970. Also invited to speak at workshop on "Research and Development of small-scale Technology", Mexican Institute of Chemical Engineers, Mexico City, July, 1970.

Publications:

"An Inter-American Program in Materials Engineering--The Utilization of Indigenous Resources For Low-Cost Composite Materials", to be published in Proceedings of 2nd Inter-American Conference on Materials Technology, Mexico City, August, 1970. (With A. T. DiBenedetto)

"An International Development Technology Center", Engineering Education, 60, No. 3, 247-249 November 1969.

"Analysis of an Oscillating Engine for Power Generation Based on the Drinking Bird Principle," Proceedings of the Fourth Intersociety Energy Conversion Engineering Conference, Washington, D. C., 624 (September 1969). (With S. S. Shergill)

"Small-Scale Power Sources for Developing Nations; An Experiment in Engineering Education," A.S.E.E. International Engineering Education Newsletter, 6:2, 1-3 (March 1968). (With R. D. Young)

"A Review and Discussion of Literature Concerning Transient Heat Transfer and Steam Formation," Report CREST-NL-2, Committee on Reactor Safety Technology, European Nuclear Engery Agency, Paris, 1-4 (December 1967).

"A Transient, Two-Region, Moving Boundary Analysis of the Drying Process," Chemical Engineering Progress Symposium Series, 63:79, 24-33 (1967). (With A. Arza

"Some Improvements to the Theory of the Submerged Evaporative Interface in Porous Materials, "Chemical Engineering Progress Symposium Series, 63:79, 14-23 (1967). (With K. H. Khokhani)

"Heat and Mass Transfer During Liquid Evaporation from Porous Materials," Chemical Engineering Progress Symposium Series, 63:79, 1-13 (1967). (With S. Yerazunis)

"International Directions for U. S. Engineering Education, "Proceedings of Conference on "Engineering in International Development," Estes Park, Colorado (August 1967).

"A Review and Discussion of Literature Concerning Transient Heat Transfer and Steam Formation," Report IDO-17226, Phillips Petroleum Company and USAEC, Idaho Falls, Idaho (March 1967).

"Heat and Mass Transfer Between an Evaporative Interface in a Porous Medium and an External Gas Stream, AIChE Journal, 13, 132-140 (1967). (With S. Yerazunis)

"The Effect of Variable Wall Heat Flux on Heat Transfer in the Thermal Entrance Region of Reactor Coolant Channels," Transaction of the American Nuclear Society, 9, 567-568 (1966). (With R. J. Page)

Contributions (Unsigned) to Argonne National Laboratory Reactor Development Program Progress Reports, ANL-7090, 60-63 (August 1965); ANL-7105, 62-63 (September 1965).

"Engineering Education for Hostile Environments," Journal of Engineering Education, p. XXVIII (April 1965).

"Definition of Engineering," Journal of Engineering Education, p. XXVI (June 1962).

Scientific and Professional Societies:

American Association for the Advancement of Science
American Association of University Professors
American Institute of Chemical Engineers
American Nuclear Society
American Society for Engineering Education
Sigma Xi
Society for International Development
Tau Beta Pi
Volunteers for International Technical Assistance

BIOGRAPHY OF FRED JEROME ROSENBAUM
Associate Professor of Electrical Engineering

Date of Birth:	15 February 1937
Academic History:	University of Illinois, B.S.E.E., 1959 M.S.E.E., 1960 Ph.D., 1963
Experience:	Research Assistant, University of Illinois, 1959-1963 Research Scientist, McDonnell Aircraft Corp., 1963-1965 Assistant Professor, Washington University, 1965-1967 Associate Professor, Washington University, 1967-present Consultant, Emerson Electric Corp., 1965-present Consultant, Monsanto Corp., 1966-present
Professional Societies:	IEEE
Honors:	Eta Kappa Nu Sigma Tau Sigma Xi
Research Experience:	At the University of Illinois, Dr. Rosenbaum was a member of the Ultra-microwave Group, directed by Professor P.D. Coleman, where he performed studies on millimeter-wave linear accelerators and high-energy electron-beam interactions with matter. As a research scientist at McDonnell Aircraft he has worked in ferromagnetic resonance, cavity and traveling-wave masers, electromagnetic surface waves, instrumentation for electric spin resonance spectroscopy and lasers. At Washington University, he has studied electromegnetic wave propagation in anisotropic ferrites, ferrite phase shifters, microwave demodulation of light, microwave phonon-electron interactions, and the properties and applications of Gunn-effect microwave oscillators.

Papers Presented:

"Cerenkov Radiation in Anisotropic Ferrites," F.J. Rosenbaum and P.D. Coleman, paper presented at the Millimeter and Submillimeter Wave Conference, Orlando, Florida, January 1963.

"Effects of Non-Uniform Population Distribution in Masers," F.J. Rosenbaum and W.G. Jeffers, paper presented at the Millimeter and Far-Infrared Conference, Estes Park, Colorado, August 1965.

"Bias Circuit Oscillations in Gunn Devices," W.C. Tsai and F.J. Rosenbaum, Informal Conference of Active Microwave Effects in Bulk Semiconductors, New York, January 1968.

"A Design Theory for Reggia-Spencer Phase Shifters," W.E. Hord, F.J. Rosenbaum and C.R. Boyd, presented at International Microwave Symposium, Detroit, Michigan, May 1968.

Articles and Publications:

"Cerenkov Radiation in Anisotropic Ferrites," F.J. Rosenbaum and P.D. Coleman, MTT, Vol. 11, pp. 302-311, September 1963.

"Electromagnetic Wave Propagation in Lossy Ferrites," F.J. Rosenbaum, MTT, Vol. 12, pp. 517-528, September 1964.

"Dielectric Cavity Resonator for ESR Experiments," F.J. Rosenbaum, Rev. Sci. Instr. Vol. 35, pp. 1550-1554, November, 1964.

"Hybrid Modes on Anisotropic Dielectric Rods," F.J. Rosenbaum, IEEE Journal of Quantum Electronics, Vol. 1, December 1965.

"Effects of Non-Uniform Population Distributions in Masers," F.J.Rosenbaum and W.Q. Jeffers, IEEE Journal of Quantum Electronics, Vol. 1, December 1965.

Articles and Publications: (continued)

"Effects of Spatial Dependence in the Single Mode Laser Rate Equations," (Correspondence), F.J. Rosenbaum and T.J. Menne, IEEE Journal of Quantum Electronics, Vol. 2, February 1966.

"Approximation Technique for Dielectric Loaded Waveguides," W.E. Hord and F.J. Rosenbaum, IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-16, No. 4, pp. 228-233, April 1968.

"Propagation in Ferrite Filled Coaxial Transmission Lines," R.S. Mueller and F.J. Rosenbaum, IEEE Trans. on MTT, October 1968.

"Theory of Suppressed Rotations Reciprocal Ferrite Phase Shifters," W.E. Hord, F.J. Rosenbaum, C.R. Boyd, IEEE Trans. on MTT, November 1968.

"Propagation in Longitudinally Magnetized Ferrite-Filled Square Waveguides," W.E. Hord and F.J. Rosenbaum, IEEE Trans. on MTT, November 1968.

"Application of Reciprocal Latching Ferrite Phase Shifters to Lightweight Electronic Scanned Phased Array Antennas," W.E. Hord, C.R. Boyd, and F.J. Rosenbaum, Proceedings of IEEE, November 1968.

"Gunn Effect Swept Frequency Oscillator," F.J. Rosenbaum and Wei-Ching Tsai, Proceedings of IEEE, November 1968.

"A Design Theory for the Reggia-Spencer Phase Shifter," W.E. Hord, F.J. Rosenbaum and C.R. Boyd, 1968 MTT Symposium Digest, May 1968.

"Electromagnetic Wave Propagation on a Ferrite Loaded Wire," R.S. Mueller and F.J. Rosenbaum, IEEE Trans. on Microwave Theory and Techniques, February 1969.

"Bias Oscillations in Gunn Devices," W.C. Tsai and F.J. Rosenbaum, IEEE Trans. on Electron Devices, February 1969.

Donald L. Snyder

Visiting Associate Professor

Electrical Engineering

Nationality: U. S. Citizen. Born January 8, 1935, Stockton, California

Education

B.S.E.E. Electrical Engineering, University of Southern California 1961

M.S.E.E. Electrical Engineering, M.I.T. 1963

Ph.D. Electrical Engineering, M.I.T. 1966

Industrial Experience

Hughes Aircraft Company, Culver City, California, Summer 1960; worked on microwave ferrite device research

Autonetics, A Division of NAA, Anaheim, California, February 1961 to August 1961; Summer 1963; worked on the processing of passive sonar signals and related topics

M.I.T. Lincoln Laboratory, Lexington, Mass., Summers, 1964, 1966, 1967, and 1968; worked on satellite AGC systems to combat jamming; study of a continous-access high-altitude satellite navigation system; study of effects and procedures for combatting atmospheric noise in communications systems

Consulting Experience

Autonetics, A.Division of NAA, Research Center, Anaheim, California, 1961-62; worked on sonar signal processing

Cambridge Technical Center, Cambridge, Mass., 1966-67; worked on acoustical signal processing

Raytheon Company, Space and Information System Division, Sudbury, Mass. 1966 to the present; worked on study of millimeter communication channels (characterization and measurement)

M.I.T. Lincoln Laboratory, Lexington, Mass., 1966 to the present; worked on Navigation systems using high-altitude satellites; the effect of atmospheric noise on communication systems

Lecturer in special (two week) courses on detection, estimation and modulation theory and its application to communication, radar/sonar problems. Lecturer in industrial courses on random process theory and detection, estimation, and modulation theory. Organizer and lecturer in a one week summer course (M.I.T., Summer, 1969)entitled "The Application of State-Variable Techniques to Communication Systems".

A. BOOKS

The State Variable Approach to Continuous Estimation, with Application to Analog Communication Theory, the M.I.T. Press, Mar. 1969.

B. Journal Articles

1. "A nonlinear study of compensatory manual control systems," IEEE Transactions on Human Factors in Electronics, HFE-5, 1. pp.25-28, Sept. 1964.

2. "Some useful expressions for optimum linear filtering in white noise," Proceedings of IEEE (Correspondence), 53,6, pp.629-630, June, 1965.

3. "Some useful expression for optimum linear filtering in white noise--II," Proceedings of the IEEE(Correspondence), 53,9, pp. 1254-1255, Sept. 1965.

4. "Optimum linear filtering of an integrated signal in white noise," IEEE Transactions on Aerospace and Electronic Systems, (Correspondence), AES-2, pp.231-232, March, 1966.

5. "A theory of continuous nonlinear recursive filtering with application to optimum analog demodulation," 1966 Wescon Conv. Record, Part I.

6. "The state-variable approach to analog communication theory," IEEE Transaction on Information Theory, IT-14, 1, pp. 94-104, Jan. 1968.

7. "Optimal binary detection of known signals in a non-Gaussian noise resembling VLF atmospheric noise," 1968 Wescon Conv. Record, Part 6.

C. Articles (not in Journals)

1. "An application of an equation for the conditional probability density functional of Markov processes to nonlinear minimumvariance filtering and estimation," M.I.T.,R.L.E., Q.P.R., No. 78, July, 1965.

2. "Analysis of a minimum-variance phase estimator by means of the Fokker-Planck equation," M.I.T., R.L.E.,Q.P.R.,No. 78, July, 1965.

3. "The state-variable approach to continuous estimation" PH.D. Thesis, M.I.T., Department of Electrical Engineering, February, 1966.

4. "Nonlinear minimum-mean-square-error filtering with application to analog communication," M.I.T., R.L.E., Q.P.R., No. 79, Oct. 1965.

5. "Navigation with high altitude satellites: a study of errors in position determination," M.I.T., Lincoln Laboratory, TN 1967-11, Feb. 1967.

6. "Comments on ELF noise," M.I.T., Lincoln Laboratory, Group Report 66, Oct., 1967.

7. "An application of state-variable estimation techniques to the detection of a spatially-distributed signal," M.I.T.,R.L.E., Q.P.R., Apr., 1969 .

D. Meeting Speeches

1. "A theory of nonlinear recursive filtering," 1966 Wescon (pub. as JA 5 above).

2. "Optimal binary detection of known signals in a non-gaussian noise resembling VLF atmospheric noise," 1968 Wescon (pub. as JA 7 above)

3. "An application of state-variable extimation techniques to signal detection for the optical cloud channel," 1969 International Symposium on Information Theory, Ellenville, N.Y., Sponsored by the IEEE Professional Group on Information Theory. (Published as article 7 above).

E. Thesis Student Publications

1. (Senior Thesis) Loffredo, Ralph, "A study of simulation techniques," June, 1967.

2. (Master Thesis) Koontz, Warren L., "Numerical analysis of a quasi-optimum FM demodulator," September, 1967.

3. (Master Thesis) Olsen, Ronald G., "Simulation of a binary phase-shift-keying communication system," August, 1968.

4. (Master Thesis) Butterfield, Stephen J. "Optimum demodulation of a phase-modulated message in the presence of phase instabilities," September, 1968.

5. (Master Thesis) Aron, Jeffrey B. "Estimation of linear system parameters based on perfect observations," August, 1968.

EDWARD GREENBERG Professor and Chairman
Department of Economics
Washington University
St. Louis, Missouri

Date of Birth: June 22, 1936

Married, two children

Academic Training

New York University	1953-1957	B.S. (1957) Economics
University of Wisconsin	1957-1961	M.S. (1959) Economics
		Ph.D. (1961) Economics

Major Field: Economic Theory
Secondary Field: Statistics
Outside Minor: Mathematics

Teaching and Other Experience

University of Wisconsin
- Teaching Assistant, Elementary Statistics, 1957-58
- Acting Instructor, Statistics, Principles, Advanced Theory, Fall, 1959
- Research Assistant, Spring 1959; Spring, Summer, Fall, 1960
- Project Assistant, Summer 1961
- Instructor, Principles, 1961-62
- Assistant Professor, Principles, Economics of National Defense, 1962-63

Washington University
- Assistant Professor, Mathematical Economics, Advanced Statistics, Theory, 1963-65
- Associate Professor, 1965-
- Ford Foundation Faculty Fellow, 1965-6

Consultant:
- Federal Reserve Bank of St. Louis 1963 -
- Social Security Administration 1965 -
- Midwest Program Airborne Television, Inc. 1963-4
- Rand Corporation, 1967 -
- President's Task Force on Communications Policy, 1968

Scholastic Honors

New York University: Deans list, Founders' day honors, Magna Cum Laude, Beta Gamma Sigma, Order of Artus
Wisconsin: University Fellow, 1958-59, National Science Foundation Fellow, Summer 1959

Publications

Business Investment in Plant and Equipment: An Empirical Study, Doctoral Dissertation, University of Wisconsin, July 25, 1961.

"A Stock-Adjustment Investment Model", Econometrica, April, 1964

"Appropriations Data and the Investment Decision", Journal of the American Statistical Association. June, 1965.

"Some Aspects of the State Distribution of Military Prime Contract Awards," Review of Economics and Statistics May, 1966.

"Employment Impacts of Defense Expenditures and Obligations," Review of Economics and Statistics May 1967.

"Wire Television and the FCC's Second Report and Order on CATV Systems," Journal of Law and Economics, October 1967.

"Television Station Profitability and FCC Regulatory Policy," Journal of Industrial Economics (forthcoming)

(with Harold J. Barnett) "A Proposal for Wired City Television" Washington University Law Quarterly, Winter 1968; "The Best Way To Get More Varied TV Programs," Trans-Action May 1968; "On The Economics of Wired City Television," American Economic Review, June 1968.

NAME: Neil Norlin Bernstein, Associate Professor of Law

ADDRESS: 557 Warren Avenue, St. Louis, Missouri 63130

DATE AND PLACE OF BIRTH: May 18, 1932 -- Cheyenne, Wyoming

EDUCATION:

University of Michigan, B.A. 1954, with High Distinction and Honors in Political Science; William Jennings Bryan Prize (outstanding political science graduate) 1954; Phi Beta Kappa.

Yale Law School, LL.B. 1957, Cum Laude and Order of the Coif; co-recipient Edward D. Robbins Prize (highest third-year grades) 1957; Yale Law Journal. Class standing: Third in class of 142.

PUBLICATIONS:

Note, "Enjoining Res Judicata," 65 Yale Law Journal 543 (1956).

Comment, "Tax Aspects of Alimony Trusts," 66 Yale Law Journal 881 (1957).

Review of Smead: Freedom of Speech by Radio and Television, 17 Fed. Comm. B.J. 51 (1959)

Review of Rostow: Planning for Freedom, 13 Journal of Legal Ed. 126 (1960).

Review of Cohen: The Legal Conscience, 1961 Wash. U. Law Quarterly 303.

With Gilbert R. Whitaker, Jr.: "Background Paper on the Communications Industry" (Prepared for Cabinet Committee on Price Stability, 1968).

Article, "The Supreme Court and Secondary Source Material: 1965 Term" 57 Georgetown L.J. 55 (1968)

Article, "Issues and Implications of the FCC Proceedings - A Response to Professor Prendergast" ([redacted] published in Public Utilities Fortnightly, March 27, ~~Spring~~ 1969)

EMPLOYMENT:

July 1957 - July 1958: Motions Clerk, U.S. Court of Appeals for the District of Columbia Circuit, Washington, D. C.

July 1958 - August 1960: Associate, Fischer, Willis & Panzer, 1735 DeSales St., N.W., Washington, D. C.

August 1960 - July 1961: Visiting Assistant Professor of Law, Washington University School of Law, St. Louis, Missouri

July 1961 - August 1967: Attorney, American Telephone and Telegraph Company, 195 Broadway, New York, New York.

August 1967 to date: Associate Professor of Law, Washington University School of Law, St. Louis, Missouri.

Summer 1968: Visiting Professor of Law, The National Law Center, George Washington University, Washington, D. C.

Barry Anderson

Assistant Professor of Education

1. Personal

a) Born January 23, 1942, Calgary, Alberta

b) Married, no children

c) Home address:

7426 Stanford Ave.
University City, Missouri 63130
Telephone (314) 863 7580

d) Office address:

Washington University
Graduate Institute of Education
McMillan Hall, Box 1183
St. Louis, Missouri 63130

2. Education

a) High School - Calgary, Alberta

b) B.Ed. University of Alberta 1959-1963
Majors in Physical Education and physical sciences
minor - sociology

c) M.Ed. The University of Alberta 1964-1966
major - Educational Administration
minor - research methods

d) The University of Toronto 1966-1968
(The Ontario Institute for Studies in Education)
major - Educational Administration
minors - sociology and research methods
Ph.D. should be awarded in spring of 1970

3. Experience

a) Teacher with Calgary Public School Board 1963-1965

b) Sessional lecturer - The Ontario College of Education, 1967-1968

c) Graduate Assistant (OISE) 1966-1968

d) Research Associate (OISE) 1968-1969

e) Assistant Professor of Education (Administration)
Washington University
St. Louis, Missouri

4. Professional Memberships
   a) American Educational Research Association
   b) Canadian Educational Research Association

5. Scholarships and Awards
   a) University of Alberta Intersession Bursary 1966 $500
   b) Ontario Institute for Studies in Education Scholarships 1966-67 $1,000
      1967-68 $2,250

6. Publications and Related Activities
   a) "Educational Reform: Process or Product" Teacher's Digest, 11 (March, 1967) pp. 11-14
   b) "Who's a Good Principal?" with A.F. Brown in The Canadian Administrator, VI (Dec. 1966), pp. 9-12
   c) "Faculty Consensus as a Function of Leadership Frequency and Style" with A.F. Brown in The Journal of Experimental Education. Vol. 36, No. 2, Winter 1967, pp. 43-49
   d) "Faculty Consensus as a Function of Leadership Frequency and Style" was also presented to the Canadian Conference on Educational Research, Winnipeg, Manitoba. June 9, 1967
   e) Leader Behavior Styles of Alberta School Principals unpublished M.Ed. thesis (Calgary: The University of Alberta, Calgary, 1966)
   f) "The Student as Nigger: Sociological Implications," paper read to the Canadian Association of Professor's of Education, Calgary, Alberta, May 30, 1968
   g) Ph.D. thesis topic: "The Relationship between Students Alienation from School and School Bureaucratization"

8. Teaching Interests
   a) Administrative Theory
   b) Social-Psychology in Educational Administration
   c) Research Design
   d) Elementary and Intermediate Statistics
   e) Seminars in Problem Solving
      Leadership
      Innovations in Education
      Social Relations in Education

9. Technical Skills
   a) Research Design
   b) Multivariate Data Analysis
   c) Questionnaire Construction and Validation
   d) Computer Programming
   e) Use of Unit Record Equipment

10. Research Interests
   a) Problem Solving at Administrative and Classroom Levels
   b) Incidental Learnings in Classroom Situations
   c) Impact of School Organization on Students and Teachers

ROBERT M. WALKER

Personal Information:

Born February 6, 1929, at Philadelphia, Pennsylvania.
Married, two children.

Academic Background:

B.S. (Physics), Union College, 1950.
M.S. (Physics), Yale University, 1951.
Ph.D. (Physics), Yale University, 1954.

Honorary Degrees:

D.Sc., Union College, 1967.

Prizes, Citations, Awards:

National Science Foundation Senior Post-doctoral Fellow, 1962.
American Nuclear Society Distinguished Service Award, 1964.
Yale Engineering Association Annual Award, 1966!
Industrial Research Magazine awards to products he helped develop in 1965 and 1966.

Experience:

G. E. Research Laboratories, Schenectady, New York, August 1954 to August 1966.
Visiting Professor, University of Paris, 1962-1963.

Honorary or Professional Societies:

Fellow, American Physical Society.
Member, American Association for Advancement of Science.
Member, American Geophysical Union.
Member, American Astronomical Society.
Member, American Institute of Aeronautics and Astronautics.
Phi Beta Kappa.
Sigma Chi.

Name of Journal without reference indicates that manuscript has been submitted.

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Publications by Robert M. Walker

1. "Cloud Chamber Investigation of Nuclear Interactions of Cosmic Rays," N.R. Whelten, R.S. Preston, R.V. Adams, R.M. Walker, and H.L. Kraybill Phys. Rev. 93, 1356 (1954).

2. "Production of Neutral V-Events by Cosmotron Neutrons," R.M. Walker, R.S. Preston, E.C. Fowler, and H.L. Kraybill, Phys. Rev. 97, 1086 (1955).

3. "X-ray Beam Measurement of Distortion in a Magnet Cloud Chamber," R M. Walker. Rev. Sci. Instru. 26, 304 (1955).

4. "Electron Irradiation of Copper Below 10°K," J.W. Corbett, J.M. Denney, M.D. Fiske, and R.M. Walker, Phys. Rev. 104, 851 (1956).

5. "Electron Irradiation of Copper Near 10°K," J.W. Corbett, J.M. Denney, M.D. Fiske, and R.M. Walker, Phys. Rev. 108, 954 (1957).

6. "Discrete Recovery Spectrum in Electron Irradiated Copper," J.W. Corbett and R.M. Walker, Phys. Rev. 110, 767 (1958).

7. Paper No. 2385, Second Geneva Conference on the Peacetime Uses of Atomic Energy (1958), D.K. Holmes, J.W. Corbett, R.M. Walker, J.S. Koehler, and F. Seitz: Reprinted in "Progress in Nuclear Energy," Series V, Vol. 3, Pergamon Press (1961).

8. "Recovery of Electron Irradiated Copper: I. Close Pair Recovery," J.W. Corbett, R.B. Smith, and R.M. Walker, Phys. Rev. 114, 1452 (1959).

9. "Recovery of Electron Irradiated Copper: II. Interstitial Migration," J.W. Corbett, R.B. Smith and R.M. Walker, Phys. Rev. 114, 1460 (1959).

10. "Energy Dependence of Recovery in Electron Irradiated Copper," J.W. Corbett, R.M. Walker, Phys. Rev. 115, 67 (1959).

11. "Spin Resonance in Electron Irradiated Silicon," G.D. Watkins, J.W. Corbett, and R.M. Walker, Jour. Appl. Phys. 30, 1198 (1959).

12. "Threshold Measurements and the Production of Radiation Damage in the Noble Metals," J.W. Corbett and R.M. Walker, Phys Rev. Letters 117, 970 (1960).

13. "On the Production of Displaced Atoms by Thermal Neutrons," R.M. Walker, Journal of Nuc. Materials 2, 147 (1960).

14. "Electron Induced Radiation Damage in Pure Metals," R.M. Walker, Proc. Enrico Fermi School on Solid State Physics, Vol. 18, Academic Press (1962).

15. "Defects in the Noble Metals," J.W. Corbett, and R.M. Walker, Proc. of Conf. on Lattice Defects, AEC Report NAA-SR-3250, Canoga Park (1960).

16. "Energy Dependence of Electron-Induced Atomic Displacements in Al, Ag, Cu, Fe, and Ni," P. Lucasson and R.M. Walker, Discussions of the Faraday Society, No. 31, 57 (1961).

17. "Electron Microscope Observation of Etched Tracks from Spallation Recoils in Mica," R.M. Walker and P.B. Price, Phys. Rev. Letters 8, 217 (1962).

18. "Production and Recovery of Electron Induced Radiation Damage in a Number of Metals," R.M. Walker, P.G. Lucasson, Phys. Rev. 127, 485 (1962).

19. "On the Variation of Radiation Damage Parameters in Metals," P.G. Lucasson and R.M. Walker, Phys. Rev. 127, 1130 (1962).

20. "Electron Microscope Observation of a Radiation-Nucleated Phase Transformation in Mica," P.B. Price and R.M. Walker, Jour. Appl. Phys. 33, 2625 (1962).

21. "A New Track Detector for Heavy Particle Studies," P.B. Price and R.M. Walker, Phys. Rev. Letters 3, 113 (1962).

22. "Observations of Charged Particle Tracks and Solids," P.B. Price and R.M. Walker, Jour Appl. Phys. 33, 3400 (1962).

23. "Chemical Etching of Charged Particle Tracks in Solids," P.B. Price and R.M. Walker, Jour. of Appl. Phys. 33, 3407 (1962).

24. "Observation of Fossil Particle Tracks in Natural Micas", RM.Walker and PB Price, Nature 126, 732 (1962).

25. "A Simple Method of Measuring Low Uranium Concentrations in Natural Crystals", PB Price and RM Walker, Appl. Phys. Letters 2, 23 (1963).

26. "A Method of Forming Fine Holes of Near Atomic Dimensions", RL Fleischer, PB Price and RM Walker, Rev. Sc. Inst. 34, 510 (1963).

27. "A Versatile Disposable Dosimeter for Slow and Fast Neutrons", RL Fleischer, PB Price and RM Walker, Appl. Phys. Letters 3, 28 (1963).

28. "Irradiation des Metaux," RM Walker, Le Journal de Physique 24, 474 (1963).

29. "Fossil Tracks of Charged Particles in Mica and the Age of Minerals," PB Price and RM Walker, J. Geo. Res. 68, 4847 (1963).

30. "Electron Microscope Studies of Charged Particle Tracks in Solids", PB Price and RM Walker, Paper 64, Int. Cong. Elec. Micros, Phila, Academic Press (1962).

31. "Ternary Fission of Heavy Compound Nuclei", PB Price, RL Fleischer, RM Walker, and EL Hubbard. Conference on Reactions between Complex Nuclei. Asilomar, 1963; U.Cal Press, A. Ghiorso, R.M. Diamond and H.E. Conzett, eds. p. 332-337.

32. "Track-Registration in Various Solid State Nuclear Track Detectors," RL Fleisher, EL Hubbard, PB Price, and RM Walker. Phys. Rev. 133A (1964)

33. "Registration of Fission Fragment Tracks in Several Substances and Their Use in Neutron Detection", M. Debeauvais, M. Maurette, J. Mory, and R. Walker. Int. J. of Appl. Rad. and Isotopes. 15, 289 (1964).

34. "Characteristics and Applications of Solid State Track Detectors", RM Walker. Proc. of Strasbourg Conference on New Methods of Track Detection (1963) Centre de Recherches Nucleaires, Strasbourg, France.

35. "Etude Des Traces De Fission Fossiles Dans Le Mica", M. Maurette, P. Pellas, et RM Walker. Bull. Soc. Franc. Miner. Crist. 87, 6 (1964).

36. "Etude Des Traces Produites Par Les Protons Dans Mica, Olivine, Et Tektites", M. Maurette et RM Walker, J. dePhysique 25, 661 (1964)

37. "Fossil Records of Nuclear Fission", Fleisher, Price and Walker New Scientist, Vol. 21, 406 (1964)

38. "Fission Track Dating of Man-Made Glasses," R.H. Brill, R.L. Fleischer, P.B. Price, and R.M. Walker, J. of Glass Studies VI, 151 (1964).

39. "Fission Track Ages of Zircons," R.L. Fleischer, P.B. Price, and R.M. Walker, J. Geophys. Res. 69, 4885 (1964).

40. "Fission Track Dating of a Mesolithic Knife," R.L. Fleischer, P.B. Price, R.M. Walker, and L.B.S. Leakey, Nature 205, 1138 (March, 1965).

41. "Effects of Temperature, Pressure and Ionization on the Formation and Stability of Fission Tracks in Minerals and Glasses," R.L. Fleischer, P.B. Price, and R.M. Walker, J. Geophys. Res. 70, 1497 (March, 1965).

42. "On the Simultaneous Origin of Tektites and Other Natural Glasses," R.L. Fleischer, P.B. Price, and R.M. Walker, Geo. et Cos. Acta 29, 161 (1965).

43. "Neutron Flux Measurement by Fission Tracks in Solids," R.L. Fleischer, P.B. Price, and R.M. Walker, Nuc. Science Engr. 22, 153 (1965).

44. "Fission Track Dating of Bed I, Olduvai Gorge," R.L. Fleischer, P.B. Price, R.M. Walker, and L.S.B. Leakey, Science 148, 72 (1965).

45. "Cosmic-Ray Exposure Ages of Tektites by the Fission Track Techniques," R.L. Fleischer, C.W. Naeser, P.B. Price, R.M. Walker, and M. Maurette, Geophys. Research 70, 1491 (March, 1965).

46. "Spontaneous Fission Tracks from Extinct Pu^{244} in Meteorites and the Early History of the Solar System," R.L. Fleischer, P.B. Price, and R.M. Walker, ~~[illegible]~~ J. Geophysical Research 70, 2703 (1965).

47. "Applications of Fission Tracks and Fission Track Dating to Anthropology," R.L. Fleischer, P.B. Price, and R.M. Walker, Proceedings of 7th Glass Congress, Brussels, June-July, 1965.

48. "Tracks of Charged Particles in Solids," R.L. Fleischer, P.B. Price, and R.M. Walker, Science 149, 383 (July, 1965).

49. "Fossil Particle Tracks and Uranium Distributions in Minerals of the Vaca Muerta Meteorite," R.L. Fleischer, C.W. Naeser, P.B. Price R.M. Walker, and U.B. Marvin, Science 148, 629 (1965). X

50. "Cosmic Ray Induced Particle Tracks in a Meteorite," M. Maurette, P. Pellas, R.M. Walker, Nature 204, 821 (1964).

51. "The Ion Explosion Spike Mechanism for Formation of Charged Particle Tracks in Solids," R.L. Fleischer, P.B. Price and R.M. Walker, J. Appl. Phys. 36, 3645 (1965).

52. "Solid State Track Detectors: Applications to Nuclear Science and Geophysics." R.L. Fleischer, P.B. Price, and R.M. Walker, Ann. Rev. Nuc. Sci., 15, (1965). X

53. "Uses of Particle Tracer Detectors in Neutron Dosimetry," J. Mory and R. Walker, Vth International Conference on Nuclear Photography, CERN (1964).

54. "Origins of Particle Tracks in Meteorites," M. Maurette, R.L. Fleischer, P.B. Price, and R.M. Walker, J. Geophys. Res., 72, 331 (1967)

55. "Heavy-Ion Tracks in Meteorites and the Elemental Abundances of Very Heavy Cosmic Ray Primaries," M. Maurette, G. Morgan, R.L. Fleischer, P.B. Price, and R.M. Walker, Proc. of the IXth Int. Conf. on Cosmic Rays, Phys. Soc. (London),

56. "Ternary Fission of Heavy Compound Nuclei by Thorite Track Detectors," R.L. Fleischer, P.B. Price, R.M. Walker, E.L. Hubbard, Physical Review

57. "Nuclear Particle Tracks in Meteorites," R.L. Fleischer, P.B. Price, and R.M. Walker, Int. Dictionary of Geophysics

58. "Fission Track Dating," R.L. Fleischer, P.B. Price, and R.M. Walker, Int. Dictionary of Geophysics,

59. "Ultrasensitive Detectors for Neutrons or Heavy Cosmic Ray Nuclei," R.L. Fleischer, P.B. Price, and R.M. Walker, Rev. Sci. Instr. 37, 525 (1966)

60. "Quaternary Dating by the Fission-Track Technique," R.L. Fleischer, P.B. Price, and R.M. Walker, Science in Archaeology, 2nd edition.

61. "Etchable Line Defects in Crystals are not Necessarily Dislocations," R.L. Fleischer and R.M. Walker, Phil. Mag., ~~Letters to Editor~~, 13, 1053 ([illegible])

62. "Nuclear Particle Tracks in Meteorites", R. L. Fleischer, P. B. Price, and R. M. Walker, Encyclopedia of Earth Sciences, Reinhold Publications, 1966.

63. "Fission Track Dating", R. L. Fleischer, P. B. Price, and R. M. Walker, Encyclopedia of Earth Sciences, Reinhold Publications, 1966.

64. "Charged Particle Tracks: Tools for Geochronology and Meteorite Studies", R. L. Fleischer, P. B. Price, and R. M. Walker, Chapter in Book - Radiometric Dating for Geologists, edited by E. T. Hamilton.

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Herbert Ohlman

Research Applied Scientist

Background

Born, New York City, March 6, 1927. Attended Bronx High School of Science 1940-44; Served in U. S. Army Corps of Engineers, 1945-47. Married; four children.

Education

B.S. in Physics, Syracuse University, 1950. Graduate work in physics at the University of Minnesota; in operations research and engineering psychology at Ohio State University; in information storage and retrieval at U.C.L.A., in library science at Rutgers University; in linguistics at the Massachusetts Institute of Technology; in computer science at Washington University.

Areas of Specialization

Information storage and retrieval	Library automation
Microimaging systems	Text processing systems
Computer utilities	Information input design
Product planning	Man-machine compatibility

Recent Experience

Central Midwestern Regional Educational Laboratory, Inc.
St. Ann, Missouri

A nonprofit corporation for innovation in elementary and secondary education in eastern Missouri, southern Illinois, Kentucky, and western Tennessee.

1967-1969

Associate Director for Educational Information Systems. In charge of the Systems Development Program, the Computer Literacy Project, and the Data Processing Center with a staff of 8 professional and 7 clerical employees in three states.

Systems Development Program: Design and development of computerized instructional management system to aid elementary and secondary teachers in decision-making regarding course content, sequencing, and evaluation for individual students.

Computer Literacy Project: Demonstrate the feasibility and acceptibility of training teachers in a student-oriented programming language so that they may introduce computer technology as a problem-solving tool for their students.

Xerox Corporation
Rochester, N. Y.

1964-1967

Product Planner, Business Development and Market Research Division. Performed product planning studies in the areas of information storage and retrieval, unconventional publishing, and engineering graphics, and analyzed the education and publishing markets for new devices and systems.

Scientist , Corporate Research Division. Performed diversification study in the area of electronic distribution systems for education, and participated in other studies in the areas of automobile safety, science kits, and microimaging systems. Also did in-depth study of the area of demand publishing, and investigated man-machine factors.

Itek Corporation
Lexington, Massachusetts

1963-1964

Head, Systems Applications Section, Information Sciences Laboratory. Supervised the design of systems for library automation, machine-stenotype translation, and document retrieval and dissemination. Headed proposal efforts in the medical information systems area.

IBM Advanced Systems Development Division
Yorktown Heights, N.Y.

1961-1962

Senior Staff Analyst, Education Exploration Project. Prepared and tested programmed text to teach a general purpose simulation language to systems engineers. Evaluated advantages and disadvantages of programmed instruction. Worked on computer-controlled simulation games for elementary school use.

Professional Affiliations

Association for Computing Machinery: Chairman, Special Interest Group on Information Retrieval, 1966-67. American Society for Information Science: Chairman pro tem., Special Interest Group on Education for Information Science, 1966; Vice-Chairman and Chairman-Elect, Upstate New York Chapter, 1967. American Association for the Advancement of Science.

Publications

Proceedings,"Symposium on the Uses of Computers in Education," (editor), CEMREL, Inc., May 1969.

"Educational Computer Trends in the CEMREL Region: Analysis and Recommendations," May 1969.

"Electronic Distribution Systems for Education," Xerox Corporation, April 1966.

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"Mechanical Indexing: Historical Development, Techniques and Critique," presented to the 23rd Annual Meeting of the American Documentation Institute, Oct. 1960.

"The State-of-the-Art of Medical Data Processing: Medical Communication and the Promise of Machines", System Development Corporation, May 1960.

"Subject-Word Letter Frequencies with Applications to Superimposed Coding", in "Proceedings of the International Conference on Scientific Information", National Academy of Sciences, 1960, vol. 2, pp. 903-915.

"A Permutation Index to the Preprints of the International Conference on Scientific Information," (with J. Citron, L. Hart), System Development Corporation, SP-44, Nov. 1958; revised, Dec. 1959.

"Low-Cost Production of Marginal-Punched Cards on Accounting Machines", American Documentation, 8 (2), April 1957, pp. 123-126.